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REPORT OF THE ENTOMOLOGIST

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., August 31, 1928.

SIR: I submit herewith a report of the work of the Bureau of Entomology for the fiscal year ended June 30, 1928.

Respectfully,

C. L. MARLATT,
Entomologist and Chief of Bureau.

Hon. W. M. JARDINE,
Secretary of Agriculture.

INTRODUCTION

The reorganization authorized by the Secretary of Agriculture July 1, 1927, and having for its purpose the bringing together into a new organization, now designated as the plant quarantine and control administration, of all plant-quarantine and related regulatory and control activities of the department, involved the transfer, effective July 1, 1928, to this new organization of the work of this nature hitherto conducted by this bureau in cooperation with the Federal Horticultural Board. The items of work so transferred include the enforcement of the quarantines on account of the gipsy and brown-tail moths, the Japanese and Asiatic beetles, the European corn borer, and, in Hawaii, the Mediterranean fruit fly. The very important research work on these subjects, in all its phases—in biology and natural and artificial control—remains with the bureau. It had long been felt that the growing volume of regulatory work was materially interfering with the development and prosecution of research work which was the primary purpose of the bureau. The separation of the regulatory from the research work will, it is believed, lead to the mutual benefit of both of these fields. A more extended statement of this reorganization is given in the annual report of the Federal Horticultural Board, to which reference is made.

Record should be made in this report of the retirement, effective October 15, 1927, of L. O. Howard from the position of chief of bureau, which he had held since 1894. The position of chief of bureau was filled by the appointment, in succession, of the writer. Doctor Howard will remain, however, in the bureau under the title of principal entomologist, to follow up work along the lines of his special interest. In other departmental publications a full and appreciative record has been made of the important work and achievements of Doctor Howard during his long connection with the department.

DECIDUOUS-FRUIT INSECT INVESTIGATIONS

Investigations of deciduous-fruit insects have been carried out under the direction of A. L. Quaintance, as formerly.

CODLING MOTH

Work on the codling moth has been largely a continuation of that started during the preceding fiscal year as related to the problem of arsenical-spray residues on apples and pears. These investigations, carried on in cooperation with the Bureaus of Plant Industry and Chemistry and Soils, and with several of the States, have shown that many of the arsenical and other compounds tested as substitutes for lead arsenate are not suitable for

use on apples and pears. A number of the compounds have been considerably less effective as poisons than lead arsenate, whereas others have caused important injury to foliage. Among the arsenates tested were those of zinc, aluminum, iron, barium, calcium, copper, titanium, manganese, and magnesium. Tests were also made of various silicofluorides. These studies are being made at the division's field laboratories at Yakima, Wash., Vincennes, Ind., Wichita, Kans., Bentonville, Ark., Moorestown, N. J., and, near by, at Sligo, Md. Since the experiments for 1927 indicated possibilities with aluminum arsenate and zinc arsenate these poisons are being further tested. The work planned for 1928 in orchards involved experiments in the use of lead arsenate at different strengths without and with various stickers or spreaders, some plats to be thus treated early in the season, for the control of the first brood and afterwards to be treated with contact sprays and ovicides for the second and later broods. Materials tested as contact sprays and ovicides included nicotine oleate and nicotine sulphate at different strengths, extracts of Derris 1 to 800, extracts of pyrethrum, and white-oil emulsions.

The rapid progress in the perfection of apple-washing machines indicates rather strongly that the use of such machines to remove excess spray residues will prove a most valuable means of meeting the residue problem. Should this be the case the continued reasonable use of lead arsenate, even under conditions of aridity, will be possible. This will be a fortunate outcome in view of the desirable qualities as a spray possessed by lead arsenate, namely, adhesiveness, noninjuriousness to foliage and fruit, and toxicity to the codling moth. Investigations to develop other spray materials will be continued, however, in the hope that something may be found which is less objectionable from the health standpoint than lead arsenate, and which will be equally effective against insects and safe for foliage. In the laboratory in Washington two investigators are devoting the major part of their time to the determination of the lethal doses of a variety of materials for this purpose and to the development of other stomach-poison insecticides. At most of the field laboratories experiments have been carried out in orchards under practical conditions. At Vincennes, Ind., tests of poisons have been made largely in the laboratory and have involved the handling

of 25,000 codling-moth larvæ, although in addition 17 small field plats have been in use. At the Yakima, Wash., laboratory it was ascertained that in control value five applications of double-strength lead arsenate were equal to six applications at the normal strength, and that four double-strength applications nearly equaled five applications at the usual strength. The use of oil sprays with lead arsenate generally gave better control than was obtained with lead arsenate alone, but the oil has certain definite effects on the tree and fruit which need further study to determine whether they constitute injury. Nicotine sulphate, 1 to 800, used in three cover sprays, following a calyx and a first cover application of lead arsenate, resulted in very favorable control. In this connection it was found that nicotine sulphate kills about 15 or 20 per cent of codling-moth eggs and has a very decided effect in checking the entrance of worms, even for from 12 to 15 days after it has been applied. To supplement spraying, further attention was given at the Yakima laboratory to the use of bait traps. It was found that by this means an important number of moths could be caught and destroyed but, in these tests, not sufficient numbers of them to effect control. In cooperation with the Bureau of Chemistry and Soils studies were undertaken in the spring of 1928 to ascertain what constituents of the fruit juice and other baits are most attractive to the moths.

Further progress has been made in the development of the automatic or self-working codling-moth bands for application to the trunk and limbs of apple and pear trees. Bands soaked in lubricating oil containing beta naphthol have continued to give good results. As a mimeographed circular giving instructions for the preparation of the bands has been issued, and as the bands have been made available to orchardists by a manufacturing concern, they will probably receive extensive tests during 1928. According to the bureau's observations the bands, if properly made and applied, are nearly 100 per cent effective in destroying all codling-moth larvæ which spin up under them throughout the season, and thus far there has been no important injury to the bark of the trees from their use. Careful studies of the possible repellent action of the treated bands as compared with untreated ones indicate that the larvæ go just as readily to the treated as to the untreated bands.

GRAPE-BERRY MOTH

As in the instance of the codling moth, investigations in the field of grape insects have been largely a continuation of the work undertaken during the preceding fiscal year in connection with the spray-residue problem. In the control of the grape-berry moth especially, midsummer sprayings have been necessary, which leave a very decided residue on the grapes at picking time. The experiments undertaken therefore have been to ascertain to what extent this and other grape insects could be controlled by very thorough early spraying with increased dosages of lead arsenate, and whether sufficient residue would persist at harvest time to exceed the tolerance allowed for arsenic. In this connection arsenates of calcium, magnesium, aluminum, zinc, manganese, iron, etc., have been tested. Tests were also made with various oils, alone and combined with lead arsenate; with nicotine sulphate, alone and combined with lead arsenate; with pyrethrum-soap combinations; with cuprous cyanide; with the fluosilicates of potassium, sodium, and barium; and with shale oils. In addition, large-scale experiments in vineyards have been carried out with commercial lead-arsenate dust in the hope that control of the berry moth could be accomplished without the usual spray-residue effect.

The results in the fall of 1927 indicated that several of these materials were worthy of further experimentation, and consequently they were put under test again in the spring of 1928. Aluminum arsenate, calcium arsenate, and tricalcium arsenate, as well as magnesium arsenate, in two experiments gave the same control of the berry moth as lead arsenate, two applications giving a fair control, whereas three applications gave notably better results as compared with the condition of untreated checks. Zinc arsenate, ferric arsenate, and manganese arsenate caused some burning of foliage or damage to grape clusters, and gave lower percentages of sound fruit. With the other materials, including lead arsenate, no serious injury to foliage was apparent. An analysis of samples of ripened grapes from these various plats, made by the food, drug, and insecticide administration, showed that with the most promising materials the quantity of arsenical residue present on grapes is approximately the same as on grapes sprayed with lead arsenate and near or above the tolerance allowed. In a large-scale experi-

ment in the field, in which spraying after midsummer against later broods of the berry moth was omitted, it was found that while the quantity of residue at harvest time was within the tolerance, the control of the berry moth was unsatisfactory. A miscible-oil emulsion and two white-oil emulsions tested at 1, 1½, and 2 per cent strengths gave poor results in the control of the berry moth. Although some of the eggs present on the berries and foliage at the time of application were destroyed, the oils did not affect the larvæ entering the grapes; furthermore, some injury to foliage resulted. The natural bloom of the grape berries was destroyed, and this effect gave the fruit an unattractive appearance. The use of nicotine sulphate at a dilution of 1 to 800 resulted in the destruction of some of the eggs of the berry moth present at the time of spraying, but did not provide sufficient protection to produce a yield of marketable grapes under conditions of heavy infestation. Similar unsatisfactory results were obtained with a commercial preparation of Derris, said to contain 5 per cent of Derris resins, when used at a strength of 1 to 800. Sodium silicofluoride was found to be highly toxic to grape foliage; it was less injurious when used with Bordeaux mixture or with lime, but its toxicity to insects was then reduced.

It would appear that the greatest hope of controlling the berry moth without objectionable spray residue will come from very intensive spraying of vineyards early in the season with lead arsenate, so that the later broods will be of minor importance; such spraying must be reinforced by certain cultural practices calculated to destroy the overwintering grape-berry moths, and such systems of vine training must be adopted as will permit of thorough spray applications. There is, of course, hope that methods of washing grapes similar to those employed in the case of apples and pears may be developed. Preliminary experiments along this line indicate, however, that there are numerous conditions to be met in the washing of grapes that are not present when apples or pears are to be washed.

PEACH INSECTS

Experiments have been continued on the Oriental fruit moth at the laboratories at Moorestown, N. J., and Fort Valley, Ga. At the Moorestown laboratory the work was principally along three lines, namely, a continuation of life-history investigations and studies

of biological control and of insecticides. The growing season of 1927 fairly concluded a detailed study of the life history and habits of the fruit moth, and the data are being assembled for publication. The investigations of biological control have dealt principally with detailed studies of the life history and habits in the laboratory and field for four species of parasites, namely, *Macrocentrus ancylovora*, *Glypta rufiscutellaris*, *Ascogaster carpocapsae*, and *Trichogramma minutum*. As the last two species also attack the codling moth, this insect, too, has been used as a host in these studies. Three years of careful field and laboratory work have now been accomplished with *M. ancylovora*, which is the most important parasite in the vicinity of the laboratory and in the southern half of New Jersey. This species is very abundant when twig infestation runs high and apparently has been responsible for a decided reduction in the number of the insect late in the season. Observations have also been made on *G. rufiscutellaris*, a form very abundant in the northern half of New Jersey, even more so than the one first mentioned. Particular attention has been given to a life-history study of the little egg parasite *T. minutum*. This parasite has a large list of hosts and readily attacks the eggs of the Oriental fruit moth and the codling moth. These studies have developed the relationship existing between temperature and the rate of development. It was found that there were at least 13 generations of the *Trichogramma* last season, and the length of the life cycle ranged from 8 to 65 days. When the temperature averaged 80° F. a generation was completed in 8 days, whereas when the temperature averaged about 50°, 50 to 65 days were required to complete a generation. A few individuals overwintered in eggs of the Oriental fruit moth. In the insecticide studies ovicides, repellents, and winter washes have been given special attention. Various winter washes to destroy the insects in overwintering cocoons were tried, but most of them gave negative results, and from our present information this method of attack is not considered very hopeful.

At the Fort Valley, Ga., laboratory most of the time was devoted to working up laboratory notes, accumulated during the years 1925 and 1926, on the life history of this species under conditions prevailing in the South. Scouting through this section showed a great increase in the area infested,

although the damage continues to be light. At this laboratory investigations of attractants and repellents for injurious peach insects have received major attention, the plum curculio and the peach borer being the forms principally involved. Preliminary work in the laboratory has been accomplished mostly by means of olfactometers, while evaporation cups and traps have been used in orchards. A large list of possible attractants have been under test against the plum curculio, and to date this insect appears rather more attracted to certain phenols than to other chemicals. Tests have been under way to determine the toxicity of the fluosilicates of sodium and calcium and of a number of arsenicals as insecticides against the plum curculio. Sodium fluosilicate without lime, both as a dust and sprayed as a mixture of 2 pounds to 50 gallons of water, was the most toxic to the plum curculio of all the insecticides tested. Spraying experiments with this compound without lime showed, however, that it was very toxic to peach foliage and fruit. Although lime corrected the burning effect of the insecticide, making it even safer than lead arsenate, it largely destroyed its toxicity for the plum curculio. Since sodium fluosilicate has several important advantages over lead arsenate for the plum curculio on peach, it will be given further attention in the hope that some way may be worked out whereby injury to foliage may be obviated. Laboratory studies have been completed on the effects of hydrogen-ion concentration upon the arsenates of acid lead, tricalcium, zinc, aluminum, barium, manganese, and magnesium. Considerable correlation has been found to exist between the burning produced upon peach foliage and the speed with which these arsenates decomposed in a solution having a pH equal to the acidity of rain or dew. Correlation was also found to exist between the toxicities to insects of these arsenicals as reported by various investigators and the speed with which they decompose in a solution of the approximate acidity of the digestive tract of an insect. These studies, therefore, suggest a possible method for the prediction of the probable comparative toxicities to foliage and insect of a series of insoluble salts of a given acid. Acid lead arsenate was found to be nearest to the ideal insecticide of all those tested. Its decomposition was the least rapid at the pH of rain and dew and the most rapid at the

approximate pH of an insect's digestive juices.

Work has been continued with paradichlorobenzene for the peach borer. It has been found, as formerly, that practically no injury results to 4 or 5 year old trees with a dosage of three-fourths ounce and to 6-year-old trees with a dosage of 1 ounce. Some of the 1-year-old trees were injured by the one-fourth ounce and one-half ounce doses for 2 and 4 weeks, and some of the 2-year-old trees were injured by one-half ounce and three-fourths ounce doses for 2 and 4 weeks. There was light injury from the one-half and three-fourths ounce doses for 4 weeks around 3-year-old trees. At the Sligo, Md., laboratory further tests have been made with paradichlorobenzene dissolved in high-test gasoline applied around the bases of peach trees. The results have shown that this method of application, without preparation of the soil before treatment and without banking with soil after application, is as effective as the application of the crystals made in the usual way. Further experiments will be necessary, however, to ascertain the exact status of this method of application of the chemical. Tests carried out with cloth bands and crêpe-paper strips treated with beta naphthol and red engine oil applied around the bases of peach trees indicate that such treatment is dangerous to the health of the trees.

At the Vincennes, Ind., laboratory further observations were made on the insects involved in the so-called "cat-facing" of peaches, especially with reference to tests of materials which might prevent the trouble. In this connection cresylic-acid dust, calcium-cyanide dust, nicotine dust, and nicotine liquid were put under test. Preliminary examination indicates that none of these materials will give a satisfactory control.

NUT INSECTS

Investigations of nut insects are subdivided into those on nut insects in general and those on insects affecting the pecan. Headquarters for the former work is at French Creek, W. Va. Here the various insects attacking nuts other than the pecan are being investigated as opportunity offers. During the last fiscal year special attention was given to parasites attacking the hickory twig girdler, which has been quite destructive at Petersburg, Va., French Creek, W. Va., and other localities. The twig girdler now appears to be on the decline,

largely owing to the valuable work of some seven or eight species of parasites which have been found attacking the eggs and young larvæ of this species. Progress was made during the year in studies of several weevils of the genus *Curculio* attacking nuts and acorns. Extensive rearings have been made of these weevils, especially of the two species *Curculio proboscideus* and *C. auriger*, both injurious to chestnuts. Special attention has been devoted to methods of destroying these weevils while they are undergoing transformation in the soil and to the preoviposition habits of the beetles on the trees. It has been found that beetles of *C. auriger* feed on fruit juices, and that the species attacking chestnuts feed freely on honey thinned with water and on water otherwise sweetened. Experiments were made to determine whether use can be made of these feeding habits to accomplish the weevils' destruction. With the blighting and dying of native chestnut trees in the East there is an awakened interest in planting other nut-bearing trees to take the place of these dying chestnuts. Thus the hazel nuts, both American and European species, are being more extensively planted than previously. Particular attention has been given to an enemy of the hazel, *Agrilus arcuatus*, which girdles and kills small twigs of these plants. In addition the hazel curculio, *C. optusus*, and two other species of *Agrilus* beetles are under study, as the three forms threatened to stand in the way of the successful growing of these nuts.

Investigations of pecan insects are being carried out, headquarters being located at Albany, Ga., and sublaboratories at Barnesville, Ga., and Brownwood, Tex. At Albany, Ga., tests are under way, in cooperation with the office of cotton-insect investigations of this bureau and with the Bureau of Plant Industry, to determine the practicability of controlling foliage-destroying insects by dusts of calcium arsenate applied by airplane. Special studies are being made of the biologies of several pecan pests, as the shuckworm, nut case bearer, etc., including their various parasites. At Barnesville, Ga., the nut weevils and certain borers which have become quite troublesome in the surrounding district are receiving major attention and satisfactory progress is being made. At Brownwood, Tex., the so-called "black pit" and "kernel spot" are receiving special attention, as well as the shuckworm, nut case bearer, and other important forms.

BLUEBERRY MAGGOT

Experiments in the field and laboratory in the Washington County, Me., area were continued during the fiscal year along much the same lines as previously, though these were materially enlarged in some particulars. In connection with the life-history investigation it has been ascertained that the flies begin to emerge late in June, increase rapidly during the first week of July, the peak of emergence being reached about the middle of the month. During the last 10 days in July emergence declines rapidly and practically ceases by August 1. It appears that the preoviposition period of the adult averages about 13 days and the period of oviposition about 6 days. Egg laying began about July 11 and reached the peak about July 28. About July 16 egg hatching was observed and reached its maximum about August 3. These observations indicate an incubation period of about 6 days at the beginning and about 5 days during the height of the season. Maggots are present in the berries in maximum numbers about August 10. At this time pupation begins, reaching its maximum about August 17. These life-history facts are utilized as a basis for the most effective application of calcium-arsenate dust to the plants, the effort being to poison the adults before they have oviposited to any extent.

Besides further tests with the poisons additional studies were made of the possible value of burning over the blueberry land, a practice heretofore much followed. It was ascertained that the burning process as ordinarily conducted failed to raise the soil temperature materially, and therefore is not effective in destroying the puparia below the surface of the soil. There are indications that double burning—that is, burning over the land two years in succession—will be more effective, since some of the puparia of the flies remain in the soil for two years before flies emerge, and are an important factor in the infestation of the first crop of berries after the land has been burned over. Experiments to ascertain the exact value of double burning are under way, but the results will not be available until the summer of 1929.

Further attention is being given to the collection of fruits of various kinds for determination of infestation by maggots. Puparia of the blueberry maggot were obtained last year from *Crataegus* sp., chokeberry, wintergreen

berries, bunchberry, mountain holly, and *Vaccinium corymbosum*. Further study was given to parasitism by *Opius melleus*, which has been found to vary from 1 or 2 per cent to 40 or 50 per cent. The adult of this parasite emerges somewhat later than the adult of its host, a fact which indicates the possibility of destroying the fruit flies by a dust application of calcium arsenate in sufficient time to permit the adults of the parasite to escape injury from the poison.

Rather extensive experiments were carried out during the year by means of high-power orchard dusters. About 50 acres was under experiment, the dosage of poison ranging from about 3½ to 10 pounds per acre. Every experiment showed considerable reduction in the number of maggots in the blueberries as a result of the treatment. Tests were also made of calcium-arsenate dust to which powdered sugar had been added. Although this experiment was somewhat inconclusive because of rather low initial infestation, the advantage of the added sugar was not very apparent in comparison with calcium arsenate powder alone. Analyses of blueberries from the poison-dusted plats gave less than 1 part of arsenic per million, and in many samples there was only a trace of arsenic at picking time. It is felt, therefore, that there is but little, if any, danger that the blueberries will carry objectionable quantities of arsenic at harvest time.

PREVENTING SPREAD OF THE JAPANESE AND ASIATIC BEETLES

This work has continued under the direction of Loren B. Smith.

JAPANESE BEETLE

During the period under review the area infested by the Japanese beetle was enlarged to include 19,827 square miles, an increase of 5,908 square miles above the area in 1927. In Connecticut 12 additional townships south of the Housatonic River, including the city of Bridgeport, were found to be infested. The discovery of new colonies of the insect on Long Island made it necessary to include the entire island within the regulated area. Infestations were found in many localities in the coal-mining region of Pennsylvania. A small infestation of beetles was found at Gettysburg, and a single beetle at York, Pa. Small colonies of beetles were discovered at Clayton and Dover, Del. Several in-

festations were located in the State of Maryland; these occurred in the towns of Cambridge, Ridgeley, Chesapeake City, Perryville, and the city of Baltimore. Several beetles were discovered in the District of Columbia.

The area heavily infested by the Japanese beetle increased considerably in 1927. Severe injury to shade trees, ornamental plants, and field crops was noted in portions of Delaware, Chester, Montgomery, Philadelphia, and Bucks Counties, Pa. Injury by the insects was evident in Salem, Gloucester, Atlantic, Burlington, and Mercer Counties in New Jersey. The periodic appearance of large numbers of Japanese beetles in the business section of Philadelphia was more pronounced than in any previous year. In general, the damage caused by the beetles was equally as severe as in former seasons. The most notable feature of the year was the severe injury to sweet and field corn resulting from the feeding of the beetle on the silk and tips of the ears. This damage was general throughout the heavily infested area. Thorough and timely spraying continued to afford excellent protection to fruit and ornamental trees. Satisfactory methods for the protection of early-ripening varieties of peaches and of small fruits still remain to be developed.

RESEARCH

Certain difficulties were encountered in the manufacture of oleate-coated lead arsenate on a commercial basis. It was necessary to spend much time and effort in improving methods for its manufacture in order to assure the production of a standardized article which would give the results desired. This material more than any other has enabled the general public to protect their plants from the attacks of the beetles, and is undoubtedly the most generally used insecticide for control of the Japanese beetle. The adhesive and spreading qualities of this material have been much improved, and under all ordinary conditions one application is sufficient to protect plants from the Japanese beetle throughout the season. Since it has been necessary to apply lead arsenate to early ripening apples shortly before they are harvested in order to protect them from attack, investigations are being conducted for the purpose of developing a nontoxic repellent which will leave no residue on the plant.

Lead arsenate has been considered a repellent rather than a stomach poison, since relatively few of the adult beetles

consume a killing dose of the chemical before they stop feeding. It has been found that when certain types of highly refined sugar sirups are combined with lead-arsenate sprays the beetles will consume a sufficient quantity of the poison to kill them. The insects usually remain on the tree or plant until they die, and many thousands of dead beetles can be observed under trees treated in this manner. Further investigation is necessary in order to overcome certain objectionable features of this mixture. When lead arsenate is sprayed on ornamental plants, the white color of the residue detracts from the appearance of the plant. To overcome this objection a green arsenate of lead was developed and has proved quite satisfactory.

An improved pyrethrum soap, prepared with a coconut fatty acid and containing sodium silicate, has been developed. It is considered a distinct improvement over the pyrethrum soap previously recommended by the laboratory, which is now being sold commercially. Investigations are being continued on the development of traps for capturing the Japanese beetle. The traps are baited with a combination of geraniol, eugenol, bran, molasses, and glycerin. Considerable improvement must be made in the design of the traps, however, before they can be generally recommended except as an adjunct to other means of control.

Progress has been made in the investigation of the use of hot water as a control for the larvæ of the Japanese beetle in balled nursery stock. Approximately 100 varieties, including 200,000 individual plants, have been treated under commercial conditions. The results show that many varieties of nursery plants can be successfully treated with water at temperatures between 110° and 112° F., and that infestations of larvæ can be destroyed without injury to the plant. The development of this treatment and its general use by the trade will effect the saving of many thousands of dollars to the nurserymen in the territory infested by the Japanese beetle. A new formula for the preparation of an improved carbon-disulphide emulsion has been developed, and the emulsion, known as miscible carbon disulphide, has been commercialized. It has been used extensively and with excellent results. Investigations have shown that under certain conditions naphthalene is an extremely effective insecticide, and work is now under way to find means whereby it may be used in soil.

Studies are being continued for the purpose of obtaining further data on the reaction of the Japanese beetle to its environment and its probable importance as a pest when it reaches other regions of the United States. At the close of 1927 it was well and firmly established in the Piedmont region of Pennsylvania. There has been some doubt whether the insect would multiply as rapidly and cause as serious damage in the Piedmont as it has done in the coastal plain area. The information accumulated during the past year indicates that the beetles have found favorable conditions for development throughout most of the northeastern part of the United States. Studies are being continued on the general ecology, life history, and biology of the Japanese beetle.

Unquestionable proof has been obtained that the dextiid parasite *Prosema siberita* has become established in the vicinity of Moorestown, N. J. Recoveries were made of adults of this parasite in New Jersey in the summer of 1927, and again in the spring of 1928. Another dextiid, *Dexia ventralis*, a parasite introduced from Chosen (Korea), has been recovered in New Jersey during the past year. The tachinid *Centeter cinerea*, introduced several years ago, has increased its distribution in New Jersey and Pennsylvania to include an area of approximately 75 square miles. Additional colonies of this parasite were liberated at Harrisburg, Pa., and Bridgeport, Conn., late in the spring of 1928. Strong colonies of the three introduced species of *Tiphia* wasps have been established in Long Island, New Jersey, and Pennsylvania. During August, 1927, the adults of *Tiphia popilliavora* were found to be extremely abundant in an area near Riverton, N. J. This colony was so vigorous that it was possible to establish 10 subcolonies in New Jersey and Pennsylvania without detracting materially from the strength of the parent colony. Shipments of the several parasites are being made from India, Japan, Chosen, and China, and the importations are being enlarged and expedited, particularly of those species which are now known to survive successfully the conditions found in this country.

QUARANTINE ENFORCEMENT

The Bureau of Entomology, cooperating with the Federal Horticultural Board and the States of New Jersey, Pennsylvania, Delaware, New York,

and Connecticut, has continued the enforcement of Federal and State quarantines to prevent the spread of the Japanese beetle. A revision of the quarantine was made in the fall of 1927. Infestations of the Japanese beetle found at points in Maryland distantly removed from the main infestation presented the problem whether large areas of uninfested territory should be included in the regulated area or whether attempts should be made to exterminate such distant infestations. There appeared to be a reasonable chance for success in an extermination campaign in the areas in Maryland, Delaware, and Pennsylvania. The Federal Horticultural Board agreed to withhold the extension of the regulated area to include Maryland until the summer of 1928, when the results of the work done there could be determined. The actual treatments for extermination were given by the several State departments of agriculture under the supervision of Federal inspectors. The treatments included the application of carbon-disulphide emulsion to approximately 5 acres of soil at each point where infestation had been found, and were concluded late in the spring of 1928. The shipment of all nursery stock from these areas was supervised and regulated by the several States in order to safeguard such movement and prevent the possibility of transporting any infestation of Japanese beetles.

During the summer of 1927 the inspection of farm products was required between June 15 and October 15; this included the inspection of fruit and vegetable products, with the exception of certain roots and seeds. The regulations require the inspection of nursery and greenhouse products, including sand, soil, earth, peat, compost, and manure throughout the year. Because of the large regulated area this method of quarantine enforcement was changed somewhat from the system maintained during previous years. Formerly the inspectors have been stationed at strategic points, subject to call by the growers. Under the new arrangement the growers presented at certain points, for inspection, their products which were to be transported from the quarantined area. Patrols were established on the majority of roads leading out of the regulated area for the purpose of preventing the movement of contraband articles of produce. It was the duty of road inspectors to examine all trucks and

vehicles passing out of the regulated area and to make sure that they carried no uncertified or contraband products. The presence of large numbers of beetles in the downtown districts of Philadelphia at certain times during the summer made it necessary at times to discontinue all inspection and certification after 10 a. m., the time when the beetles usually become active.

The inspection and certification of nursery stock and ornamental plants has been conducted on much the same basis as in former years. Improved methods of soil treatment have been devised whereby it is possible to destroy any infestation of the Japanese beetle which may exist in the soil about the roots of plants. All treatments of plants are given under rigid safeguards and are supervised by specially trained inspectors. The total number of plants certified for shipment out of the regulated area during the past calendar year amounted to 76,155,423. These were consigned to 48 States, Canada, Mexico, and many foreign countries. Ten thousand two hundred and six carloads of sand or soil were shipped from the regulated area to all the States and to Canada, 525 carloads of manure, 5,905,021 packages of farm products, and 55,507 bales of hay and straw; 25,279 boxes of cut flowers were inspected and certified for shipment from the regulated area. A total of 711,689 certificates for shipment were issued during the year.

Eight thousand one hundred and fifty-eight nursery plants were treated under field conditions and 17,674 plants were treated by the tank method. In addition, 2,166 cubic yards of potting soil were fumigated under the supervision of inspectors in the several nurseries.

Ninety-five bona fide violations of the quarantine regulations were discovered. Twenty-six of the cases were prosecuted, 2 held in abeyance, and 67 filed without action. A total of \$430 was collected by the courts in fines.

As a means of determining the spread of the Japanese beetle from year to year scouting crews were established in the territory adjacent to the periphery of the known infested area. Intensive scouting brought to light in 1927 infestations in the State of Maryland, the District of Columbia, and elsewhere. It is possible by this means to obtain fairly accurate information relative to the distribution of the Japanese beetle.

ASIATIC BEETLE

Investigations of the Asiatic beetle, *Anomala orientalis*, have been continued and enlarged during the year. A small field laboratory has been established at Westbury, N. Y., for the purpose of studying the biology of this insect, as well as to devise improved methods for its control. It has been found that certain parasites which are effective against the Japanese beetle are also useful in the control of the Asiatic beetle. Efforts are being made to establish the several species of Japanese-beetle parasites in Long Island and Connecticut to assist in the control of the Asiatic beetle. As the Japanese beetles also occur in small numbers in both of these areas, the establishment of the parasites at suitable points will be of great help later in controlling the Japanese beetle as it becomes more abundant there.

OTHER BEETLES

Preliminary studies of another beetle from Japan known as *Auto-serica castanea* Arrow, occurring in the vicinity of New York City and on Long Island, indicate that it is a somewhat serious pest. It feeds at night on many ornamental plants, as well as on fruit, and causes considerable damage. Still another Japanese species closely related to this insect has been discovered on Long Island. It is known as *Serica similis*, and is reported as injurious in Japan. Thus far it has been found in very small numbers, and it has not yet been possible to determine whether it may prove a pest in this country.

WORK ON THE GIPSY MOTH AND THE BROWN-TAIL MOTH

The activities of this project have been continued with A. F. Burgess in charge.

RESEARCH WORK

The investigations in foreign countries during the year have included (1) surveys in Italy, northern Africa, and central Europe, (2) biological work, and (3) shipment of parasites to the gipsy-moth laboratory at Melrose Highlands, Mass. No infestations were found in Italy that were large enough to produce parasites in sufficient quantities for shipments, but it was possible to forward several small shipments from Algeria. Owing to

delays in transit, the shipments did not arrive in this country in good condition, and only a few hundred live specimens of *Tricholyga segregata* and *Brachymeria intermedia* survived. An attempt has been made to breed up this material to increase the stock for colonization. Two entomologists have carried on work in central Europe with headquarters at Budapest. Biological investigations have been conducted with the parasites that appear likely to prove of importance if they can survive in America, and particularly those species that have more than one generation in a year and require a secondary host. Some progress has been made, but more work of this type is urgently needed. During the summer of 1927, 100,000 parasites, chiefly in the dormant stage, were collected in Poland and Hungary and shipped to the Melrose Highlands laboratory. These were mostly tachinids, although some hymenopterous parasites were forwarded.

During the year over 4,600,000 parasites have been liberated, over 4,000,000 of which have been the egg parasites *Schedius kuvanae* and *Anastatus bifasciatus*.

Collections from many parts of the infested territory indicate that the average percentage of parasitism is slightly greater than was that of the previous year 1926-27, the two egg parasites above mentioned, *Apanteles melanoscelus*, *Compsilura concinnata*, *Sturmia scutellata*, and the predacious beetle *Calosoma sycophanta* showing some gains. By using a specially designed trap which was referred to in the report of the last fiscal year some surprising records of the population of this beetle have been obtained. Over 2,000 beetles per acre have been collected from some selected areas, and this emphasizes the important rank which this beetle holds among the natural enemies of the gipsy moth.

Parasitism of the brown-tail moth has increased somewhat, although the small larvæ in the winter webs have been attacked a little less than usual.

In the summer of 1917 a bacterial disease, *Streptococcus disparis* Glaser, was introduced from Japan and liberated in the field. Specimens of gipsy-moth larvæ were found in small numbers this year which appeared to have died from this cause. Whether or not this species will increase more rapidly in the future remains to be determined.

Recent experiments with the use of fish oil as an adhesive for lead-arsenate sprays have shown that effective

results can be obtained with a reduced dosage of poison. The quantity has been cut this year from 6¼ to 5 pounds of lead arsenate to each 100 gallons of water for field application, and further tests are under way to determine whether even less poison can be used on all kinds of foliage and reliable results be still obtained.

Experiments in dusting by airplane did not give uniformly favorable results in the summer of 1927. One of the great difficulties encountered was the ease with which the dust was washed from the foliage by rain. Accordingly an attempt is being made to find some type of sticker that will remedy this difficulty, and several materials are now being tested.

QUARANTINE AND INSPECTION IN COOPERATION WITH THE FEDERAL HORTICULTURAL BOARD

On July 1, 1927, the gipsy moth and brown-tail moth quarantine was revised, and 13 towns in northern Vermont and 2 in Connecticut were released from the quarantined area. This release was not sufficient, however, to reduce materially the inspection work for the quarantined area as a whole. On July 1, 1928, the foreign quarantine prohibiting the shipment of Christmas trees to the United States from a tier of towns north of the international line in Quebec was withdrawn, and such action was made possible as a result of the effective eradication measures enforced by the Dominion of Canada, resulting in the apparent extermination of the gipsy-moth colony near Henrysburg, Quebec, which was the basis of the quarantine.

The following shipments were inspected and certified during the year, those that are recorded as infested having been cleaned before they were allowed to move: In all, 133,585 shipments were inspected and certified. These comprised 34,833 shipments of nursery stock, none of which was infested; 6,365 shipments of forest products, 35 of which were infested; 90,478 shipments of stone and quarry products, 24 of which were infested; and 1,909 shipments of evergreens, none of which was infested. In the 35 infested shipments of forest products were found 1,890 egg clusters, 84 larvæ and pupæ, and 1 adult of the gipsy moth, and 1 egg cluster and 1 adult of the satin moth. In the 24 infested shipments of stone and quarry products were found 339 egg clusters and 776 larvæ and pupæ of the gipsy moth and 5 adult brown-tail moths. The number of permits issued for the movement of

products originating outside the quarantined area was 851, and the number of permits authorized by regulation No. 6 of quarantine No. 45 was 9,168.

The number of shipments is not an accurate index of the quantity of material certified or released under permit, as a shipment may mean a car-load or barge load of material forwarded under one certificate or a single tree, shrub, or block of granite sent as an individual order. The volume of nursery stock certified during the year was greater than usual, but shipments of stone and quarry products and Christmas trees declined slightly.

EXTERMINATION WORK IN NEW JERSEY

For the first five years after the gipsy moth was found in Somerville, N. J., every effort was made to discover and treat all the infested localities, and many difficulties were experienced during that period. This work involved an area of over 400 square miles. In 1925 this region was handled by scouting localities where colonies had been found previously, and other areas under suspicion of infestation. The greater part of the work was done in a belt of towns approximately 10 miles in width, beyond the periphery of the known infested area, to determine the possible spread of the insect. This general plan has been continued since that time, the purpose being to close in gradually on the area that was originally infested. Each year the scouting has been intensified and has been followed up by thorough cleaning and spraying throughout the area where there was any trace of the insect.

The southern part of the area has been relatively free from infestation, but the work in the fiscal year 1927 developed the fact that a few small colonies were present in the heavily wooded territory north of Somerville and also in the township of Mendon; in all, 12 small colonies were found and treated. During the present fiscal year these areas have been reexamined, as also have the following townships or parts thereof: Branchburg, the southern part of Hillsboro, a section of Montgomery, Franklin, the western portions of North Brunswick, and a considerable area in North Plainfield. Five small colonies, aggregating 70 egg clusters, have been found, two of these being in Hillsboro, two in Warren, and one in North Plainfield. The scouting has been more intensive than

ever before, and, as the northern part of the territory is heavily wooded, progress there is relatively slow.

All the spraying was done in the spring, as planned, although the extremely wet season caused considerable delay. Two thousand four hundred and twenty-nine shipments of trees and other material were inspected and certified, in accordance with the provisions of the New Jersey State gipsy-moth quarantine.

The results of the season's work in New Jersey have been very gratifying, and continued progress has been made in the extermination of the insect in that State. Hearty and effective cooperation with the State department of agriculture has been maintained as heretofore.

THE BARRIER-ZONE PROJECT IN NEW ENGLAND AND NEW YORK

Work on the barrier-zone project was begun in the spring of 1923, in cooperation with the department of conservation of the State of New York.

In the report for the fiscal year 1925 attention was called to the rapid increase of the gipsy moth in the Cape Cod section of Massachusetts, and it was pointed out that if this condition should develop in the western part of the quarantined area the barrier zone would be threatened.

Infestation in the eastern part of the area became worse in the fiscal year 1926, the area defoliated being more than doubled. A few infestations large enough to cause some defoliation were also found at Springfield, Vt., and Deerfield, Mass., on the west side of the Connecticut River, as well as at points east of the river and in New Hampshire. The infested areas were treated by State and town officials.

To determine the trend and amount of increase near the barrier zone, two groups of towns lying directly east of the zone in Vermont were examined during the fiscal year 1927. Three heavy infestations were found in that State, one each in Pittsford, Rutland, and Ira. The colonies were promptly treated, and no infestation has since been found in the localities named. Had the colonies been allowed to increase for another year or two, the adjoining towns in the zone would have become infested.

Early in the spring of 1927 reports from the State and local authorities working in the territory between the zone and the Connecticut River in Massachusetts showed that the in-

crease in the number of egg clusters over that of the previous year amounted to 215 per cent.

During the summer of 1927 the area defoliated in the eastern part of the territory nearly doubled, marked increases in area occurring in Massachusetts and New Hampshire, while in Maine the largest acreage of defoliation was recorded since the gipsy moth was first found in that State. In Rhode Island more defoliation occurred in the southern part of the State than had ever been noted in previous years.

The results obtained and the reports of State and local authorities indicate clearly that the infestation in many areas has continued to increase. In some towns many small infestations are present in all sections of them. This situation makes the problem far more difficult than heretofore, and forecasts a heavy spread of the pest into the barrier zone as soon as these small, scattered colonies have sufficient time to increase. Some of these colonies are so near the eastern line of the zone that heavy spread may occur unless effective work is carried on before the larvæ hatch in the spring of 1929.

Conditions in the barrier zone show improvement in the northern and in the southern part, except in the town of Wallingford, Conn., where a large woodland colony was found in 1928. The territory in the southern part of Berkshire County and in northern Connecticut developed more infestations than usual and is now the most threatening area in the zone. Several colonies were found in 1928 in the New York area of the zone by the New York State department of conservation, immediately west of the area just mentioned. These are larger infestations than have usually been discovered in that State.

Although complete information is not now available, it is known that the acreage of defoliation in New Hampshire in 1928 will far exceed that of the last few years, and it is believed that the total defoliated area for the entire infested district will be considerably larger than in 1927. Heavy defoliation occurred farther west in Massachusetts and New Hampshire than heretofore; several small areas have been reported in southeastern Vermont, and in a few towns west of the Connecticut River in Massachusetts considerable partial defoliation was found. The continued increase in defoliation during the past four years

has reached a point where it will be necessary to carry on scouting and control operations in a wider belt of territory in the western part of the area if the advantages that have been secured in the barrier zone are to be maintained.

The infested territory along the eastern and northern peripheries of infestation in Maine, New Hampshire, and Vermont has not been inspected for several years. This work has been deferred on account of the more pressing needs in the zone area and because no serious infestations were known to occur that indicated the likelihood of immediate danger. On account of the rapid increase and annual movement of defoliated areas toward these borders, a band of towns should be scouted during the present fiscal year to determine more accurately for quarantine purposes the extent of spread of infestation.

CEREAL AND FORAGE INSECT INVESTIGATIONS

Investigations of cereal and forage insects have been carried out under the direction of W. H. Larrimer, as formerly.

EUROPEAN CORN BORER

The gradual spread of the corn borer toward the Corn Belt from the region of the Great Lakes has continued during the year, and although the benefits derived from the clean-up campaign of 1927 were substantial in preventing commercial damage to the corn crop the natural spread of the insect by flight has continued. This is particularly true of Ohio and Indiana, where the areas found infested in 1927 were considerably greater than was the case during the previous summer. Much of the spread in Ohio occurred in an area that was contiguous to the section which it was necessary to exempt from clean-up in 1927. In this connection it should be observed that some of the apparent spread of 1927 may have occurred in 1926, but owing to the less adequate scouting facilities available in that year this infestation may not have been discovered until 1927, when a greater and more efficient scouting corps than ever before was thrown into the field. It is believed that as a result of this action the limits of the territory occupied by the corn borer are now more exactly known than ever before. In this connection it is inter-

esting to note that the area found newly infested in southern Michigan in 1927 was much smaller than it was the previous year. The western boundary of the infested territory has now reached the center line of Indiana on the west and has advanced beyond central Ohio on the south. A more detailed report on results of scouting and other quarantine activities will be found in the annual report of the Federal Horticultural Board.

As a result of the continued urgent demand of the Corn Belt States for all possible protection from the inroads of the corn borer, the first session of the Seventieth Congress passed an act authorizing an appropriation of \$7,000,000 for the conduct of a second control campaign, with the objective of reducing the natural spread of the pest. Under the program proposed by the department for the administration of this act, the work was to have begun in the fall of 1928, but the Congress adjourned without appropriating the necessary funds.

By the terms of the appropriating resolution which failed of passage it was stipulated that adequate regulations be promulgated by all of the States involved and that assurance of the satisfactory enforcement of such regulations be given before the department could begin any work under the act. Therefore, in order to enable the department to function under the recent act in case the next session of Congress should appropriate funds in accordance with the terms of the existing resolution, it will be necessary for the States involved to issue regulations so early that the farmers in the control area may receive adequate warning to enable them, in the fall of 1928, to refrain from sowing small grains in fields that contain cornstalks and stubble. Unless this action is taken, a condition will result which will render the conduct of such a campaign most difficult if not impossible.

The corn-borer research work has progressed most satisfactorily during the year. The concrete results of the investigations on control up to the close of 1926 were published as Technical Bulletin 53 of the department in December, 1927.

The work of introducing the European parasites of the pest has gone forward steadily, and they are being colonized as rapidly as possible in all parts of the affected territory where infestation is sufficient to insure them a fair chance of establishment. Thus far seven species have been recovered,

indicating that they have become established. Department Circular No. 14, reporting on this phase of the work, was published in October, 1927. The general subject of the parasite complex and other controlling factors in the various life zones in central and southern Europe has been discussed in Technical Bulletin 59, issued in April of the present year. The studies of the reactions of the pest to varying environmental conditions and its economic status as regards corn production in Europe, which have been progressing for the past four years, will be concluded at the end of the present growing season. A progress report of these investigations is in press. Additional technical assistance has been furnished the European parasite laboratory, and supplementary funds have been allocated for adequate expansion of the work of parasite introduction and distribution during the coming year.

SUGAR CANE MOTH BORER

The moth borer is one of the limiting factors in the production of sugar cane in Louisiana and constitutes the principal insect problem encountered by that industry. During the spring of 1927 it threatened most serious injury to the valuable P. O. J. varieties of disease-resistant seed cane, and the sugar interests of Louisiana appealed to the department for an allotment of \$50,000 for dusting this and other varieties with sodium fluosilicate in an attempt to insure an adequate supply of dependable seed cane for planting in the recently flooded areas of that State. Although the department realized that negative results might and probably would be obtained, it was felt that the good that might be accomplished should the experiment prove successful would be so great and far-reaching as to justify the expenditure. The request therefore was granted, and arrangements were promptly made to have some 5,000 acres of cane dusted from one to three times by airplane in an efficient and expeditious manner. The results of this work, however, were disappointing. The average net kill was only 20 per cent of the insects, which was far too low for control. It was apparent from this experiment that reliance for control should be placed on other methods, and chiefly on the soaking of the seed cane in water at air temperatures previous to planting—a method which has been determined by departmental experts to be both safe and efficient.

HESSIAN FLY

Estimates made in July placed the loss caused by the Hessian fly in the Kansas wheat crop of 1927 at 20,000,000 bushels. The affected area involved not only southern Kansas but also northern Oklahoma, where heavy losses also occurred. Some reduction of the crops of 1927 by the fly occurred also in Pennsylvania, Maryland, and Virginia. Severe fall injury to the winter wheat crop of 1928 followed, particularly in early planted fields in both the eastern and western regions previously mentioned. In Kansas and Oklahoma spring infestations in 1928 were much modified by weather conditions unfavorable to the fly, but in Pennsylvania, Maryland, and Virginia spring infestation in some localities and early planted fields resulted in lodging and material thinning of the stand.

Coordinated, systematic study of the Hessian fly, its parasites, and its control have been continued. The long-term experiments to determine the optimum time for sowing wheat to escape fall infestation are still in progress. Studies of the comparative fly-resistance of different wheat varieties and the factors responsible are being continued.

MORMON CRICKET

For at least 10 years past the Mormon cricket, which really is a large long-horned grasshopper, has caused the ranchers of the Great Basin, and particularly those of Sanders and Lake Counties, Mont., and of Rout, Rio Blanco, and Moffatt Counties in northwestern Colorado, serious trouble by destroying their forage crops. Some years ago it was determined that these crickets could be poisoned by modifications of the ordinary poisoned baits used for grasshoppers, but owing to the scarcity of water, the cost of the baits, and the inaccessibility of their ingredients, control by these methods was not found generally practicable. Efforts were made by the bureau, therefore, to discover if possible some less expensive and more simple and easily applied remedy which would not involve the use of water. This end seems now to have been achieved in the use of sodium-arsenite or calcium-arsenite dusts, and these have been applied successfully for the control of this pest during the past spring. A large-scale demonstration was arranged with State officials which, it is believed, proved fully the practicality and economy of this method of control.

OVERFLOW WORM

In the summer of 1927, after the subsidence of the flood waters in the Mississippi Basin, there appeared on overflowed lands in the valley of the Black River in Arkansas the larvæ of a cutworm often called the "overflow worm" and known to science as *Agrotis ypsilon* Rott. This was reported to the department, and an expert was dispatched to help in the fight against the pest. The damage had already been done, however, and the worms had largely disappeared before he could reach the scene of the outbreak. In July of the present year a similar outbreak developed, and the Bureau of Entomology was notified in time to permit its expert to act with the farmers and aid in the work of instructing them how to poison the insect. As a result the pest was completely controlled and large acreages of crops were saved.

WHEAT JOINT WORM

Until July, 1926, the wheat joint worm was not known to injure wheat grown west of the Rocky Mountains. At that time, however, a colony of this pest was discovered to be infesting wheat on farms near Malalla, Clackamas County, Oreg., and subsequently a similar infestation of small extent was found near Lebanon, Linn County, in the same State. In view of the fact that in the Eastern States this pest has been known for more than 80 years as one of the most serious enemies of wheat, these infestations have been kept under constant surveillance; and as they are increasing rapidly in intensity a circular of information regarding the wheat joint worm is being issued in cooperation with the Oregon State Experiment Station.

ALFALFA WEEVIL

At this writing the full report of the survey to determine the annual spread of the alfalfa weevil is not available, but the insect has been found in Nebraska for the first time at Henry, Scotts Bluff County. This discovery is important because the insect is now approaching closely to one of the greatest centers of alfalfa production in the country.

The investigation to determine the potentiality of alfalfa-meal mills in the possible distribution of the pest through commerce, which was begun in a tentative way last year, was provided for by action of Congress last winter and has been strengthened by

the appointment of a trained investigator who will devote his entire time to this problem.

The work of introducing the foreign parasites of the pest is being continued.

INVESTIGATIONS OF INSECTS AFFECTING STORED PRODUCTS

E. A. Back has continued in charge of investigations relating to stored-product insects.

DRIED-FRUIT INSECTS

During recent years various troubles which impair the quality of California dried fruits have become increasingly prevalent. The work of the dried-fruit-insect laboratory at Fresno, Calif., for the year has been largely concerned with the problem of reducing damage to figs, not only in storage but also in the field, where much of the trouble begins. During the early part of 1927 a large quantity of the 1926 crop of California figs was so wormy and so infested with molds that many shipments were seized and destroyed under the provision of the food and drug act. When it is understood that an estimated 10 to 12 per cent of the California fig crop was thus removed from the market, the seriousness of the situation can be realized.

During the ripening, drying, and storing of figs much loss is sustained by the growers owing to the prevalence of disease and insect attack. The diseases are known as endosepsis, smut, and souring. Although many have believed that insects play an important part in the spread of the diseases, it was not until the past year that definite proof was obtained that endosepsis is carried and spread by the dried-fruit beetle. What rôle as disease carriers is played by thrips, mites, and vinegar flies has not been determined.

Among the insects particularly destructive to figs are the dried-fruit beetle, vinegar flies, the Indian-meal moth, the fig moth, and the saw-toothed grain beetle. Of these, a careful survey indicates that the saw-toothed grain beetle becomes troublesome only after figs have been in storage for some time. The Indian-meal moth and the fig moth become active pests late in the season in figs stacked in boxes or stored in bulk on ranches, both in ranch buildings and in orchards and dry yards, and continue in the packing houses, where they espe-

cially the Indian-meal moth, surpass the dried-fruit beetle in destructiveness. But during the ripening and drying period no other pest is as important as the dried-fruit beetle, not only because of its rôle as a disease carrier but also because of its capacity to destroy the texture of the figs.

Although considerable attention has been given during the past year to studies of the biology of the fig insects, particularly the dried-fruit beetle, the Indian-meal moth, and the saw-toothed grain beetle, and while many new data are being secured almost daily, the main effort of the bureau experts has been concentrated along the line of practical control. Orchards and packing houses have been inspected in cooperation with owners; trapping experiments in orchards have been undertaken with specially devised traps, to determine if possible a relationship between insect abundance and the prevalence of diseases; fumigable storage bins for packing houses have been invented and installed, and experiments conducted in them that have established beyond question the practicability of safeguarding the crop from insects, once it is properly stored. Tests with various new and promising fumigants have been made. In cooperation with the Bureau of Chemistry and Soils, many analyses of fumigated figs have been obtained to determine what effect, if any, fumigations have upon dried figs. Much time has been given to establish, by inspections of thousands of fig samples, the relative importance of various defects due to insects and diseases in consignments of figs offered for sale by growers.

During the year the work has had the hearty support, financial and otherwise, of the California Dried Fruit Association, and most cordial relationships exist between Federal, State, and county agencies. Several progress reports have been prepared and distributed to fig growers and packers.

FUMIGANTS

Attention has been called in previous reports to the cooperative work being conducted with the Bureau of Chemistry and Soils for the purpose of discovering and testing new fumigants. A noninflammable and nonexplosive fumigant that will not adversely affect food products is much needed. Considerable progress in the investigation has been made during the year. Laboratory tests of over 300 aliphatic compounds have indi-

cated 65 that are lethal to the rice weevil in dosages of less than 6.4 pounds per 1,000 cubic feet. Of these 65 compounds 17 were selected as showing promise of commercial value and were tested on a larger scale. Ethylene oxide and methyl monochloroacetate proved slightly more toxic than carbon disulphide and were lethal to stored-product insects at a dosage of 1 pound to 1,000 cubic feet of space. The ethyl and isopropyl esters of monochloroacetate were only slightly less toxic.

Ethylene dichloride in admixture with carbon tetrachloride in the ratio of 3 parts by volume of the former to 1 of the latter has been found lethal at a dosage of 6 pounds per 1,000 cubic feet. It is a cheap, non-inflammable, and nonhazardous fumigant and is already finding extensive use for the treatment of infested furniture, fabrics, etc. It can not be recommended for the fumigation of certain fatty or oily foodstuffs because of the taste imparted to the treated product.

The isopropyl formate-carbon tetrachloride mixture, although slightly less toxic than ethylene dichloride, is better adapted to the fumigation of foodstuffs.

In general, the compounds showing the greatest toxicity were found in the following classes: Iodides, bromides, mercaptans, thiocyanates, isothiocyanates, disulphides, oxides, epichlorohydrin, halogenated ethers, and formates.

Germination tests with wheat indicated that the chlorides, formates, sulphides, disulphides, thiocyanates, isothiocyanates, and mercaptans, in dosages more than sufficient to kill weevils, do not injure the germination of grain. The iodides, halogenated alcohols, epichlorohydrin, halogenated ethers, oxides, and esters of halogenated fatty acids are injurious to the germination of wheat and should be used with caution.

BEAN WEEVILS

During the 1926 bean harvest of the San Joaquin Valley in California it was found that about 70 per cent of the farmers' consignments of beans grown in San Joaquin, Stanislaus, and Merced Counties were infested with bean weevils upon arrival at the warehouse. In the latter part of 1927 the outlook became so threatening that the Secretary of Agriculture was requested by leading agricultural and civic organizations in the region to establish

a laboratory at Modesto. In response to these requests, the Secretary directed the removal of the bean-weevil laboratory from Alhambra to Modesto, Calif.

County, State, and Federal agencies have been cooperating in a most praiseworthy manner during the year in an endeavor to reduce the infestation of the bean and cowpea crops to a negligible degree by community effort in the destruction of bean-weevil breeding places, both on farms and in bean warehouses.

GRAIN INSECTS

During the latter part of the year a definite beginning was made to further a knowledge of the insects attacking flour and of the methods for controlling pests in milling establishments. For years several controls have become standard in the milling industry, but it is believed that a thorough investigation will develop new practices that will be more effective and more economical.

The work in regard to corn weevils throughout the Gulf Coast States has been conducted as in the previous year. The experiments continue to emphasize the possibility of thoroughly protecting corn in storage from attacks of the weevils. The importance of insect control in corn bins in relation to field infestation, animal feeding, and farm economy can not be overemphasized. Although a number of new fumigants have been used experimentally in corncribs, none superior to carbon disulphide has yet been discovered.

FURNITURE PESTS

The demands upon the department for information regarding furniture pests have continued to grow during the year. When the insect problem is more completely understood it is believed that the present emergency will gradually disappear. The bureau has been very active in the distribution of information to manufacturers, retailers, and householders. The principal pests involved are the clothes moths (*Tineola biselliella* and *Tinea pellionella*) and the tow bugs (*Lasioderma serricornis* and psocids) and the furniture carpet beetle (*Anthrenus vorax*), locally destructive in the District of Columbia.

New devices for the protection of furniture in storage have received much attention. Experiments in fumigating furniture with heat and gases have been continued. The business of

treating furniture for the destruction of insects has continued to grow in all large cities. It is believed that if the recommendations of the department are followed fully 90 per cent of the present losses will be prevented.

Five papers dealing with the practical control of furniture pests have been published during the year.

MOTH-PROOFING SOLUTIONS

A more general use of the so-called moth-proofing solutions has come about during the year, and the work of the department with these solutions has continued. Experiments have demonstrated that the proper application of the best solutions imparts a moth resistance to fabrics that is of practical value. This is true in spite of the fact that the same solutions applied as sprays in a haphazard manner by the average housewife have been proven unreliable. Whatever moth resistance is imparted by solutions appears to be the result of the thorough impregnation of the fabric, preferably before the goods leave the manufacturing plant. Fabrics should be thoroughly immersed in or wet with the solution.

CEDAR CHESTS

The investigation of the value of red-cedar chests as protectors against ravages by clothes moths, under way for several years, was brought to a close during the year with the issuing of a general statement to the public.

Investigations have determined that chests in good condition and made entirely of properly dried three-quarter inch red-cedar heartwood can be depended upon to protect clothing placed in them, provided all of the older moth worms, or larvæ, are removed before the garment is stored. Such chests will not kill the adult moths, the older worms, or the pupæ, nor will they prevent eggs from hatching. However, this is of little importance, for no injury is caused by the moth in the miller, egg, or pupal stage, and ordinarily only eggs or very young larvæ are present when garments are placed in cedar chests. Before storage in the chests the larvæ that are one-half to fully grown should be removed from garments and other susceptible fabrics by brushing, sunning, fumigation, or dry cleaning. The young larvæ that are present at the time of storing or that hatch from the eggs present on the clothing are quickly killed by cedar chests made as above described.

Experiments have demonstrated that clothes moths can complete their entire life cycle in certain veneered chests. Chests containing a back and bottom of solid three-quarter inch red-cedar heartwood, but with ends, front, and top of neutral wood veneered on the inside with one-sixteenth inch cedar have not proved dependable as moth destroyers. Chests should contain at least 70 per cent of red-cedar heartwood in the body proper. Chests made entirely of three-quarter inch red-cedar heartwood, with or without covers of neutral wood, and veneered or stamped on the outside in various hardwoods or patterns to match period furniture can be had. The mere odor of cedar, such as is imparted to chests of drawers, boxes, chests, etc., by thin veneers over neutral woods, is of no practical value.

INVESTIGATIONS OF TROPICAL, SUB-TROPICAL, AND ORNAMENTAL-PLANT INSECTS

The investigations of tropical, sub-tropical, and ornamental-plant insects have been, as formerly, under the direction of A. C. Baker.

NEW LABORATORY QUARTERS

During the year the new laboratory at New Orleans was occupied. This laboratory, equipped with all modern facilities, was made available through the cooperation of the parking commission of New Orleans, which financed its construction. Numerous problems of value to different industries are under investigation at the laboratory. The relative values of different oil sprays for the camphor scale are being worked out, and these oil studies have extended to the work on citrus. Several of the technical phases of the effect of oils on citrus fruits, described later, were handled in New Orleans, although the treatments themselves were made in Florida. The study on the influence of environmental factors on predators, also discussed later, is being made at the New Orleans laboratory, and this laboratory has recently undertaken an investigation of some of the fundamental problems in connection with fumigation with hydrocyanic-acid gas.

In Mexico City excellent laboratory buildings with suitable grounds were provided for the work on the Mexican fruit worm. These laboratories were obtained by reason of the cordial cooperation of the Oficina para Defensa

Agricola. They have been equipped with control apparatus permitting the duplication of known climatic conditions. Although field studies on the fruit worm are being carried on in different sections of Mexico, climatic conditions in these regions differ from those of the fruit regions of the United States. The equipment at these laboratories, however, will permit an exact measurement of the activities of the fruit worm under conditions similar to those of the various American fruit regions into which the insect may be introduced.

INVESTIGATIONS ON CONTROL METHODS

Bulb-insect investigations have provided a new dry treatment for bulb flies in fumigation with calcium cyanide. This is done in specially built fumigation boxes which handle the standard trays used by the growers. The cost of such boxes is relatively low, and the cost of the treatment per ton is about 50 cents, in strong contrast with about \$15, the cost with the vacuum method. This latter method, on account of its greater simplicity, was used instead of the hot-water treatment in localities not infested by nematodes; and the sanction of the new method by the plant quarantine and control administration will permit its use wherever the vacuum method has been in operation.

In connection with the hot-water treatment of bulbs for the bulb fly, a study has been made of the influence of the treatment on the stock. This has had two phases, (1) the effect on planting stock and (2) the effect on forcing stock. Results on the second phase only are available. These show that, under proper conditions of treatment, flower production from the commercial viewpoint has been satisfactory. In order to duplicate commercial conditions, treatments have been made in different parts of the country and the bulbs shipped to Washington for forcing.

Although from the commercial viewpoint results with the hot-water treatment have been good, a careful quantitative study has shown some influence on the flowers. In the daffodil groups, the flowers are consistently though slightly smaller than those from untreated stock, with occasional slight crimping, and in the case of the polyanthus narcissi there is a small decrease in the flowers per spike and in stem length. The effects of the treatment appear to be not in the percentage of flowering, but in the flowers

themselves. These influences show consistently in the analysis of the measurements taken, but would be unobservable to any but the most experienced eye. Under excessive treatment, of course, a heavy crimping of the flowers and other injuries are obvious, but these may be taken as an evidence of treatment under improper conditions.

Studies have been continued on a treatment of date offshoots by heat to rid them of scale infestation. In the method first worked out for such treatment heating to the point of killing the terminal bud was believed to be necessary; this set back the young tree nearly three years. Later investigations, aimed at a margin of safety between the death of the scale and that of the bud, have indicated that the scale can be killed at a temperature around 115° F., whereas the bud is not killed until the temperature reaches about 127°. It is planned to utilize this margin in developing a commercial method and thus save the long setback to the offshoots.

A study of the influence of the usual oil sprays on the maturing of citrus fruits has been completed. Practically all citrus-producing States now demand a standard of maturity before fruit can move in the trade. This test is based on a certain ratio between the total soluble solids and the citric acid. Anything influencing this ratio, therefore, would affect the date at which the fruit might legally be considered mature.

The oil sprays reduce the percentage of total soluble solids in citrus fruits, but the reduction is all brought about shortly after the spray application. At first the decrease in citric acid is delayed by the spray, but later the acid decreases faster than in the unsprayed fruit. When the faster decrease of acid extends over a period of three or more months, the decrease is sufficient to give an increased ratio regardless of the decrease in total soluble solids. The study has therefore shown that if the oils are applied at least three months before fruit is expected to reach the legal ratio, it will be advanced in maturing. If, however, the fruit is sprayed within three months of that time, its maturing is retarded. Even if the spray is applied a month before the fruit normally reaches legal maturity, the date of maturity may be delayed a week. With later applications the delay is much greater. In view of the high prices paid for early fruit and the declining prices as fruit comes on the markets

in increasing quantities, this matter becomes of considerable economic importance. The objects of the study were (1) to determine the influence of the spray, and (2), in case this proved to be important, to work out an economic timing of the applications. Since the sprays do not affect the flavor of the fruit in so far as could be detected, their influence on late varieties may be ignored. With the early varieties, however, the delay caused by spraying may result in heavy losses. Results, therefore, show that where early varieties are to be marketed before December, spraying should be done before July 15 or delayed until after the fruit has been picked. By this procedure insect control can be obtained without interference with the maturing of the early fruit, so it can go on the markets in time for the high prices.

BIOLOGICAL INVESTIGATIONS

Data on the habits of the lesser bulb flies have been obtained. These throw considerable light on the disputed point as to whether the attack on the bulbs by the larvæ is of a parasitic or of a saprophytic nature. Past experiments have appeared to give conflicting results. There are, however, two periods when attack may be expected. During the dry season, when the bulbs have hardened off, results have all been negative. Although a heavy oviposition on the bulbs was observed, the resulting larvæ were unable to penetrate, and infestation therefore resulted only when access was permitted by other agencies. During the moist season, however, the reverse proved to be true, and heavy direct attack occurred. This was in a large measure associated with the going down of the tops when the neck of the bulb became soft before hardening off. Direct attack, therefore, is prevalent when conditions are suitable for such attack.

A study of the developmental history of the narcissus bulb fly has been completed and results published.

Field studies on the susceptibility of the tomato and of pure races of Guatemala avocados to attack by the Mediterranean fruit fly have been conducted in Hawaii. So far as the studies have gone these crops have been proved to be free from attack.

In an attempt to determine the causes of the varying success with predators, a study of the embryonic development and oviposition rate of the Australian ladybird beetle has been

undertaken, special attention being given to the influence of environmental factors on its oviposition and development. An attempt was made to check the causes of wide variations thought to be due to origin or strains from different regions. Thus far the study shows that the variability is independent of the strain and is due to other causes.

A study of the populations of the citrus thrips in California has been continued. Wide fluctuations in the populations from year to year have led to an attempt to plot these fluctuations with the hope of determining their causes.

DEVELOPMENT OF EXPERIMENTAL METHODS

Two experimental methods have been reported on. A modified field method for determining oil in oil emulsions has been perfected. This employs 20 or 30 cubic centimeters of the emulsion and concentrated acids after the emulsion is discharged.

A method for determining low wind velocities to which the anemometer will not respond was devised and tested. A single-unit Pitot tube was employed with readings on a two-arm horizontal manometer. Two methods were tried, one taking alternate readings on the two arms and the other taking simultaneous readings. Little difference was found in errors by either type of reading.

QUARANTINE AND ERADICATION

The season's work, in cooperation with the Federal Horticultural Board, on the enforcement in Hawaii of the quarantine against the Mediterranean fruit fly and in the Rio Grande Valley of Texas of the quarantine and control work against the Mexican fruit worm, handled by this division from the middle of September until the close of the fiscal year, is reported by the Federal Horticultural Board.

TRUCK-CROP INSECT INVESTIGATIONS

Investigations on insects infesting vegetables and truck crops have been continued under the general direction of J. E. Graf.

MEXICAN BEAN BEETLE

Biological studies on the Mexican bean beetle showed that one generation of the insect developed annually in New Mexico, two in Ohio, and three, with a partial fourth, in Alabama.

The first adult appeared in the field in Alabama on March 31, whereas none were found in Ohio until May 25. The survival of hibernating forms during the winter was rather low in Ohio, varying from a maximum of 1.91 per cent to a minimum of 0.75 per cent. Surveys in southeastern Ohio indicated that there was a distinct gap between generations, with the result that beans planted when the overwintered beetles were becoming scarce escaped heavy infestation. Natural enemies of the bean beetle have not been a factor in the control of this insect in any part of this country, although eggs of a native parasite of the beetle, *Phorocera claripennis*, were found on from 5 to 8 per cent of the Mexican bean-beetle larvæ at Newport, Tenn.

Numerous tests of new insecticides have been made for the control of this insect. As in previous years the best results were obtained by the use of magnesium arsenate or calcium arsenate. Sodium fluosilicate gave good control, but on some occasions caused injury to the plants. Cage tests indicate that pyrethrum extracts are very toxic to the bean beetle, and dilutions five to eight times greater than those used against the Japanese beetle were effective. These extracts did not always give satisfactory control in the field under conditions of heavy infestation, probably because of the lack of residual toxicity and the difficulty of reaching all of the insects.

Studies on climatic conditions favorable to the bean beetle have shown a rather definite correlation between large populations of the beetle and low evaporation, but in determining the exact relationship of these factors the availability of suitable hibernation quarters must be considered. In general, the insect has been more numerous and has done more damage throughout the Southern and Eastern States than in the previous two years. The spread into new territory has been greater than in any previous year. At the present time it is found adjoining the important bean-growing areas in New York and Michigan.

As in former years, the hibernation of the Mexican bean beetle in New Mexico was found to be definitely limited to altitudes at which the yellow pine and oak are found in association. Although the survivals above the range of this association averaged less than 1 per cent, the winter survival within the yellow pine and oak association ranged from 10 to 28 per cent. Below

this zone in the piñon region about 16 per cent of the beetles survived the winter, whereas in the short-grass region of the valleys all of the beetles perished.

SWEET-POTATO WEEVIL

Studies on the control of the sweet-potato weevil have been continued in the States of Mississippi and Alabama in cooperation with State organizations. During the year over 4,500 farms were inspected in the two States concerned. The work in both Mississippi and Alabama has been conducted along the lines followed for the past several years, i. e., scouting work, including inspection in sweet-potato fields, storage banks, seed beds, and shipping sheds. In addition to the regular scouting work, all of the fields on infested properties were thoroughly cleaned at harvest, and in spring the old seed beds on all properties previously known to have been infested were cleaned, and the planting stock was kept under supervision. Careful inspections were made on farms which were near infested properties. The progress in reducing the number of infestations has made it possible to give closer supervision to this work. At the end of the year 12 farms were known to be infested in the counties of Pearl River and Hancock in Mississippi, and 23 farms were known to be infested in the counties of Mobile and Baldwin in Alabama. In Florida and Georgia the Baker-Charlton area was released as free from the weevil, as a thorough inspection within and around the originally infested area did not disclose the presence of weevils. This campaign was initiated in 1919, and 250 farms were found to be infested at one time or another during the experiment. No weevils have been found in this area since 1924.

SWEET-POTATO WIREWORM

A study of root-feeding insects affecting the sweet potato was initiated as a result of numerous complaints of injury to sweet potatoes. It was found that most of this injury resulted from wireworm attack, and on collecting and rearing the insect responsible for the damage it was found to belong to a genus of wireworms new to North America. The life history and habits of this pest are under observation, but it is still too early to indicate the possible life cycle of the insect or to give advice on the most promising methods of control.

SEED-CORN MAGGOT

The seed-corn maggot has been reared through the winter on the eastern coastal section of the Carolinas, but its activity and occurrence during the summer have not been followed. Occasional adults have been trapped during the summer in the vicinity of potato fields, but no information which shows how these insects spend the summer is available. A large brood of larvæ occurs from March to early in April and is responsible for the injury to seed potatoes. The apparent attraction of the adults to spinach seedlings is probably due to the presence of fertilizers near the surface of the soil. Work on remedies has not been completed, but through cooperative studies with the Bureau of Plant Industry the indications are that injury to seed potatoes can be avoided by the application of cultural practices and proper handling of the seed.

Studies on the food requirements of the maggot have shown that the insect is primarily phytophagous, but that the attacked seed must be in a state of germination to render it suitable as food.

SUGAR-BEET LEAF HOPPER

Fundamental studies on the ecology of the sugar-beet leaf hopper have been continued from the previous year. The investigation of the environmental complex will, it is believed, furnish an important working basis for entomologists. Surveys in South Dakota and Idaho were completed during the year, and other surveys now planned include Montana and portions of New Mexico. These will undoubtedly provide a basis for estimating the probable economic distribution of the insect, a most important question to farmers and mill owners. The State of Oregon was carefully surveyed during the past year, but owing to varying conditions there are several details yet to be worked out. It is probable that further studies will indicate localities which may be so safe from severe attack by the leaf hopper as to justify the cultivation of sugar beets. Explorations for parasites have thus far failed to produce promising results. Some parasites have been found in Mexico, but apparently all of these are already established in California. The exploration, however, has served to show that the insect's known range in Mexico extends at least 500 miles south of the border.

The prediction of outbreaks of the insect has been limited, as in the pre-

vious year, to the Twin Falls area in Idaho. At an early date farmers were informed of the great danger attending beet growing there during the present year. The prediction for injury by the leaf hopper was fully borne out in the Twin Falls area before the end of the fiscal year 1928. Indications are that injury to the east of this area will be somewhat heavy, but it will be impossible to predict this injury with assurance before harvest. It appears at this time that the forecast for injury in the Twin Falls area has, through the reduction of plantings, prevented enormous losses, and demands have been made for the extension of this service to areas in eastern Idaho and California.

STRAWBERRY WEEVIL

Studies on the biology of the strawberry weevil in the vicinity of Chadbourn, N. C., showed that the earliest weevils to appear fed on chokeberry buds but did not oviposit within them. The earliest feeding took place on wild hosts, but as soon as the strawberry buds appeared the weevils moved from the woodland to the strawberry fields. From catches on sticky screens placed about the edges of the fields and within woodlands, it was estimated that about 85 per cent of the beetles hibernated in the first 100 feet of woodland adjoining the strawberry fields. The survival of larvæ in cut strawberry buds varied largely with weather conditions and with the type of bud in which oviposition had taken place. The buds which opened on drying were the ones most favorable for the survival of the insect. Only one generation of the beetles appeared during the year. As in previous years the best control was obtained from a mixture of lead arsenate and sulphur.

RASPBERRY APHIDS

Biological studies on three species of raspberry-infesting aphids are being made with reference to the manner and time of transmission of the raspberry mosaics and the various stages during which transmission is possible. Field studies to determine the aphid population throughout the season have also been conducted, but as yet these studies have not shown any particular relationship to the transmission of the disease. Observations on the relative abundance, time of appearance and disappearance, and periods of migration of the raspberry aphids have been particularly considered.

TOBACCO STALK BORER

Heavy injury to tobacco grown as a source of agricultural nicotine in New Mexico and Arizona resulted in the initiation of a part-time study to determine the insect responsible for the injury, and the means of preventing losses. The insect was found to be the tobacco stalk borer; it lives normally on several of the wild nightshades, but subsequent to the planting of tobacco it had transferred its attacks to that crop. Experimental fields, ranging in size from a few acres to 40 acres, were very severely injured, some of them being abandoned. At this time it is impossible to state whether a practical control for the insect will be possible, owing to its wide dissemination on wild hosts, but a study of its life history is being undertaken in the hope that the information thus gained will lead to the development of practical remedies.

CELERY LEAF TYER

Experiments for the control of the celery leaf tyer did not give as successful results as had been expected. The most effective insecticides either exposed the celery to a dangerous arsenical residue, or, in the case of pyrethrum, were expensive and had little residual effect. The latter material was utilized by many of the growers, a choice which undoubtedly resulted in the saving of considerable quantities of celery. Tests with sprays were not promising, on account of the heavy foliage covering the celery rows. Studies to discover an indirect control of the insect were undertaken in cooperation with the plant board of Florida, the board leading in studies of the biology and ecology of the insect and the relation of the growth of the celery plant to infestation by the celery leaf tyer. Studies on parasites and experiments on a small scale in the colonization of egg parasites were undertaken to determine the usefulness of natural enemies. Although no definite results were obtained, the parasitism noted in the field gave hopes that heavy colonization of egg parasites at the proper time might prevent a damaging infestation of the celery. Plans have been made for testing out on a large scale the hibernation of the egg parasites.

PEPPER WEEVIL

The pepper weevil has continued to extend its zone in southern California, and Ventura County was found to be

infested during the year. Infestation was fairly general in the principal pepper districts of southern California. Field infestations were noted July 1 and the first and second settings of peppers were safe from attack before the insects became numerous. Owing to the mild winter the weevils were active and depended on nightshade for food after the disappearance of the pepper plant. The insects were controlled successfully by using from 3 to 11 applications of calcium-arsenate dust. Dusted plots averaged 1,600 pounds of peppers in excess of the checks. Peppers for canning were freed from residual arsenic in the canning process, but it was found necessary, in order to free from dangerous arsenical residues the peppers used for drying, to wash them. Studies are now under way to discover the exact rôle of nightshade as an alternate host of the insect, since information on this factor will indicate the possible value of clean culture. These experiments are being conducted in cooperation with the California experiment station.

BROWN VEGETABLE WEEVIL

Arsenicals have again proved of value against the larvæ of the brown vegetable weevil, but, in order to escape the possible hazard of dangerous arsenical residues, experiments are now under way to develop a poisoned bait which will be effective against the adults. In Mississippi certain dehydrated vegetables properly moistened have proved attractive to the beetles, even in the presence of their food plants, and barium carbonate has shown indications of being a suitable bait poison, since its use for control has given some results which were even superior to those of the arsenicals. Owing to the cost of dehydrated vegetables, an effort is now being made to dilute the bait carrier with such materials as bran and sawdust in an endeavor to reduce its cost. Owing to the aestivation of the adults, the baits, in order to control the insect, must be most attractive before it deposits its eggs. For the first time beetles were found aestivating beneath the bark of trees. Studies for the control of this insect are being initiated in California in cooperation with the California experiment station.

WIREWORMS

In southern California experiments were continued to determine the movement of wireworms in the soil and

their concentration at baits. Although a variety of materials was tested, wheat, beans, and corn proved the most attractive. Wheat apparently was more attractive to the insect than any of the other materials used. Narrow rows of bait (2 feet in width) attracted a considerably higher proportion of the wireworms than did bait rows 3, 4, and 5 feet in width. Dehydrated vegetables soaked in various poisons were tested for lethal efficiency, but no promising results were obtained. The indications were that the poisons repelled the wireworms. The experiments showed plainly that additional information on the biology and habits of the wireworms must be obtained before much progress can be made in controlling them.

In the State of Washington further studies were made on the biology and control of wireworms. Studies were made on the effect of temperature on various stages of the insect, and it was found that development was greatly accelerated under high temperatures (75° to 80° F.). Careful studies on the effect of temperature, moistures, and types of soil on the habits and development of the insects are being made. Tests with fumigants have shown that the use of either calcium cyanide or carbon disulphide is practicable on small, intensively cultivated areas. The carbon disulphide, although expensive, gave excellent results. This material gives promise of extended use in the high-priced trucking districts, where the cost of application is of less importance than freeing the soil of wireworms. Further studies on the hibernation of wireworms showed that the greatest number in hibernation were from 8 to 18 inches below the surface, a distance which was also below the frost line.

COTTON-INSECT INVESTIGATIONS

Investigation of cotton insects have been carried out under the direction of B. R. Coad, as formerly.

COTTON-BOLL WEEVIL

The crop-growing season of 1927 was marked by a general increase in serious depredations by the boll weevil, in contrast with conditions in several years preceding, and was accompanied by a similar increase in interest on the part of farmers in measures for controlling the weevil. Conditions in the earlier part of the season of 1928 were much the same, and it seems evi-

dent that the weevils have returned to a more normal activity than has been the case during the recent years of extreme climatic control. The increased damage is, of course, accompanied by a marked increase in operations for commercial control.

Studies on the hibernation of the weevil have been continued on a broader basis than heretofore, both by the bureau and by the cooperators of the various State experiment stations that are carrying on similar experiments. A number of new points of observation have been added at strategic locations in the South, especially in Georgia and Alabama, and the picture of seasonal activity of the weevil is thus becoming steadily more complete.

In the studies of boll-weevil control at Tallulah less attention has been devoted to the plat type of test and more to strictly fundamental research. The studies of swath width were seriously interrupted by the overflow of 1927, but some additional tests were fitted in on cotton planted late after the water receded and much more definite conclusions are now available on numerous questions relative to problems of swath width with different types of machines and with the adhesion of poison under various conditions. One striking result of this progress has been the definite demonstration of a swath of approximately 15 rows as the maximum in width which can be efficiently treated with any type of machine now available, except the airplane, and the inability of the so-called cloud-drift method to give efficient distribution over the wide areas claimed for it. It had been hoped that it would be possible to recommend an increase in width of swath for the type of machines involving wheel traction, but results show this plan to be impracticable; and it is generally indicated that swath widths can not be increased safely with machines of low nozzle velocity; further, that the greatest hope for success along this line lies with machines of high nozzle velocity, particularly those with air velocities of 100 miles per hour or more.

In conjunction with this study observations have been continued on the technic and usefulness of the newer types of dusting machines, especially those of high nozzle velocity; and the possibilities and capacities of the types now available on the market have been fairly well determined. Obviously there is still room for considerable improvement in this class of dust-

ing machines. At the same time very promising progress is being made in the application of the improved principles of this type of machinery to equipment which is less expensive and of smaller capacity. The development of cotton-dusting attachments for use on cultivators has progressed far enough to show rather definitely the prospects of success, the main problem being the devising of machinery suitable for the wide diversity of types of cultivators utilized in different districts. Machines for use on the riding type of cultivator are now extensively used in field work, and improvements and modifications are being made as suggested by results. A small tractor has been provided, and equipment suitable for use on this class of motorized cultivator is being constructed and tested. Work is also under way on the improvement of the older types of dusting machinery, with special reference to making them suitable for the various dusting compounds they are now called upon to distribute. As a result the technic of dusting is being steadily improved, both as regards ground machinery and as regards airplane dusters. Several new types of airplanes have been equipped and studied in operation, while the equipment previously available has been employed extensively in standardizing and improving the methods of its use. This form of dusting is becoming a considerable factor commercially, as apparently something like 500,000 acres of cotton was dusted by airplane in the United States in 1927, besides the acreage dusted on other crops. So far the indications are that airplane dusting on the 1928 crop will be considerably greater than heretofore.

A new line of experimentation on the boll weevil has been undertaken in South Carolina. For a number of years this division has been studying methods of quickly determining the severity of attack by the weevil, and this work has finally been carried to the point where a reasonable series of observations can be depended on to give reliable information, which in turn may be utilized as a basis for giving advice on weevil control. To advance this work more rapidly a program of cooperation was perfected between the Bureau of Entomology, the South Carolina State experiment station, and the extension service of South Carolina, under which an extensive series of observations is made weekly by bureau representatives and transmitted to the extension authorities so that they may prepare timely

recommendations and give timely advice to the farmer. This type of cooperative research and extension is still in the experimental stage, but it is hoped that with sufficient experience similar to that now being gained it will be possible to organize such a service throughout the more seriously injured areas of the Cotton Belt and thus make possible intelligent weevil control with the maximum chance of success.

A comparatively heavy emergence of the weevil in South Carolina in the spring of 1928 has permitted carrying out some plat tests of early poisoning, to clear up certain points which it has not been possible to work out during the past several years of comparatively light emergence. At the same time the detailed studies of hibernation and emergence have been continued in South Carolina as representing southeastern conditions, and for contrast with the records being made in the Mississippi Delta at Tallulah.

The conditions resulting from flood in 1927, and the consequent total absence of cotton in certain large districts near Tallulah, have offered an unusual opportunity for studying the distribution of weevils entering, and again on emerging from, hibernation. Consequently the studies of weevil flight by use of field screens, which have been conducted in South Carolina for the past several years, have been relocated in the Mississippi Delta and greatly enlarged, so that they include a wide diversity of exposures as regards presence and absence of cotton last year and the abundance or lack of shelter for hibernation. This same series of experiments also includes a general study of habits of weevil movement, and with it has been combined the field testing of attractants which have been developed in the chemotropic experiments to the point where they are attractive on a laboratory basis. The field tests, of course, are the final trial to determine whether or not these materials which are attractive to the weevil in the laboratory can be made of commercial use in the field. One interesting feature of this work so far has been the unexpectedly widespread infestation of cotton by the weevils in the spring of 1928 throughout those areas where there was no cotton in 1927, thus indicating a greater movement of weevils into hibernation, and also a greater movement into the field than has been generally believed to be the case in the past.

Another new organization for control of the boll weevil has been established in the State of Oklahoma, where

climatic conditions were such during 1927 that very unusual damage by the weevil was experienced and where there was great uneasiness as to the probability of a repetition of such damage. Here the work has been two-fold: In the first place, stations for plat tests have been established at Synnewood and Durant, where thorough tests of various methods of controlling the weevil which seem to be most promising under conditions prevailing in Oklahoma are being conducted to serve as a basis for future recommendations in that State. In addition, a program of cooperation with the experiment station and with the college and extension workers has been perfected, under which an intensive study is being made of the field activity of weevils throughout the threatened portions of the State, this information being used as a basis for timely advice along much the same plan as that already described for the State of South Carolina. Thus this type of experimental cooperation is in practice under the extremely different conditions of South Carolina and Oklahoma, and it is hoped that this experiment will make possible recommendations for much more effective control of the weevil in the future.

At Tallulah the plat tests are largely devoted to the continuation of the studies on the measure of loss of cotton from different degrees of infestation. These studies have been under way for many years and are most useful after a long series of records has been accumulated. The studies include tests of the most promising of the newer insecticides which have shown sufficient effectiveness in the laboratory and in cage tests to warrant trial in the field. Laboratory and cage tests are being carried on as usual with a long series of chemicals and suggested remedies for the weevil.

COTTON HOPPER

Studies of the cotton hopper have now been rather completely reorganized with considerably less attention to field-plat tests and more to a study of the biology of the insects concerned, as well as fundamental studies of the possibility of transmission of disease in an effort to determine the nature of the disorder caused by these insects. Control studies are under way, and especial attention is being devoted to the problem of the exact nature of the toxic action of sulphur on both the nymphal and adult stages of these insects and their related species. Various outbreaks throughout the Cotton

Belt are being studied wherever possible, and especial attention is being devoted to the causative species, together with their local life history and host plants other than cotton. It now seems possible that while *Psallus seriatus* is generally the causative species for this class of damage in Texas, other species, particularly *Lygus pratensis*, are usually the principal offenders in other territory except possibly in the extreme Southeast, where *Psallus* again becomes the predominant species. Control by dusting with sulphur has usually proved at least fairly satisfactory in the field, but obviously will still stand much improvement, and there are still occasional cases of complete failure of this method to be accounted for and eliminated if possible.

ARIZONA WEEVIL

The Arizona weevil continues to increase in cultivated cotton in the Southwest, and although during the year it has not been found in any areas where it was not previously reported, it has been found more abundant throughout these areas than ever before. In the upper regions of the Santa Cruz River between Nogales and Continental, Ariz., the increase in infestation in cultivated cotton has been particularly marked, and evidently this area is serving as a breeding ground for large numbers of weevils which are infesting cotton fields more remote from natural infestations. Since eradication of the weevil in nature seems hopeless, and since even partial eradication is not feasible at the present time, an effort is being made to develop a means of reducing and holding to a minimum this danger zone, which is producing weevils that constitute a menace to other areas. The biological and other work has indicated the possibility of restricting population by certain field clean-up measures, and several hundred acres of cotton near Tubac, Ariz., has been selected for use as experimental areas in the tests of various repressive measures. The scouting work in the mountains has been practically completed as far as the area infested by weevils is concerned, but it has been found desirable to reopen this investigation in some areas north of Tucson for the purpose of working out the exact distribution of the plant in a slightly overlapping zone where the weevil is not now known to be present but where there is serious possibility of its occurrence. The biological investiga-

tions at an isolated ranch have been continued and show a steady adaptation of this insect to conditions of cotton cultivation. The number of individuals produced in this field each year increases very steadily, and gradual changes in their habits are becoming evident. This study is exceedingly important in determining the exact nature of the future activity of this insect in case it becomes established in cultivated cotton over a long series of years. Several manuscripts have been prepared dealing with the different phases of the problem of the Arizona weevil, particularly with biological studies and studies of the weevil's distribution in nature.

PINK BOLLWORM

Research investigations on the pink bollworm have now been undertaken on an elaborate scale. The first few months of the work were devoted to becoming familiar with the territory and the problem involved. Next, a cooperation with the Texas State Experiment Station was entered into, under which the State and Federal funds are administered jointly, and one organization financed from both sources has undertaken the experimental work. Headquarters are located at El Paso, Tex., with an extensive biological laboratory at Presidio; sublaboratories have been located at Balmorhea and Marfa, Tex., and Tlahualilo, Durango, Mexico, as well as temporary laboratories at other points where the needs of the work justify. There is now under way a complete study of the life history and habits of this species in all of the infested districts. Especial attention is being devoted to hibernation, survival, and emergence, with particular reference to the effect of different cultural practices on winter survival. Furthermore, recent experiments have given strong evidence of the influence of the wind in the spread of this species, and owing to the importance of this problem in connection with proposed eradication or regulatory measures a complete study, from every possible angle, of flight habits is under way. The pink-bollworm studies begin in the Laguna district of Mexico and extend northward as far as the species has been found in the United States.

In connection with the pink-bollworm project cooperative plans have been worked out with the division of agricultural engineering of the Bureau of Public Roads, covering studies of spe-

cial cultural methods for increasing mortality in the winter, and also methods of incineration or other disposal of gin and oil-mill waste which has been shown to be exceedingly dangerous material as providing for the concentration and later spread of the pink bollworm. So far the methods of getting rid of the large accumulations of such dangerous materials have been exceedingly crude. It is hoped that more efficient methods can be devised and some system perfected under which the future accumulation of such nuisances will be prevented.

COTTON BOLLWORM

During the past several years the cotton bollworm or corn earworm has been increasingly injurious in many areas from Alabama westward, and the changed methods of cotton production which have come about since the investigations of this species that were conducted a number of years ago have opened up many new problems regarding the elimination of this damage. Furthermore, definite information on the effectiveness on bollworms of methods for poisoning the boll weevil is seriously needed. For several years the bollworm infestation has been particularly heavy in the vicinity of Bryan, Tex.; this center has therefore been selected as headquarters for special studies on this species, and a series of studies on control, life history, and habits are now under way. The State experiment station of Texas has a similar project, and the work has been so arranged that the results of both Federal and State workers can be combined and correlated.

COTTON LEAF WORM

The cotton leaf worm was decreasingly abundant in 1927, and so far has not been found in the United States in 1928; investigations on this species have therefore dealt largely with an effort to obtain more definite information on the exact location in South America where it breeds up for flight to the United States, and the local conditions which give rise to such flights.

INSECT ACTIVITY IN THE UPPER AIR

Of especial interest during the year have been the studies on insect activity in the upper air. These were started first in the effort to trace the direction of flight of migrating leaf-worm moths, and have included a long

series of releases of small balloons with return tags. These have brought very interesting information on the normal directions of travel of air currents from various districts in the South. At the same time, by the use of insect-collecting traps carried between the wings of airplanes, it was soon found that an unexpectedly large number of insects are present in the upper air, although many of these are insects which possess little or no power of flight and thus are obviously carried involuntarily by air currents. These facts are so important in connection with the various questions of spread and movement of different cotton insects that a very extensive series of records has been inaugurated and will be carried out through different districts. So far it seems that the stronger fliers, although influenced to a certain extent in their directions of travel by the air currents, are able to confine themselves to comparatively low altitudes and have rather definite control over their directions of flight; the weaker fliers, however, are not so successful in offsetting air currents and apparently many of them are carried as absolutely by these currents as if they had no will in the matter. Species which have never before been suspected as possibly being wind borne have been caught at great elevations, and since these observations were begun other types of records have been made on several cotton insects, particularly the pink bollworm and cotton hopper; and there is every indication that wind transportation may be a very important factor in their spread. Extensive observations are being made to check up on these points.

INVESTIGATIONS OF INSECTS AFFECTING MAN AND ANIMALS

This work has been continued under direction of F. C. Bishopp, as formerly. In order the better to administer this developing and important line of research, headquarters were transferred from Dallas, Tex., to Washington, D. C., late in the fall of 1927.

SCREW WORM

Investigations relating to the screw worm and other blowflies which attack livestock have been continued along lines similar to those of last year. Further studies of the efficacy of various baits for use in trapping these flies and of the methods of preventing the breeding of flies in the materials used for baits have been

conducted. This work has shown clearly the importance of preventing the bait pans from becoming dry at any time and has also demonstrated that the period of effectiveness of meat baits may be greatly lengthened if a proper condition of moisture is maintained.

Large-scale tests of fly trapping under range conditions have been continued in cooperation with the Texas Agricultural Experiment Station, and further information has been obtained indicating that where trapping is properly done a material reduction of the number of screw-worm cases in live-stock may be expected. It was found that the efficacy of certain traps was lowered greatly by the entrance into them of great numbers of tumblebugs. In other cases lizards, and in still other cases wrens, were found to enter the traps very frequently. Experiments indicate that these invaders can be excluded without decreasing the number of flies caught by placing wire of one-quarter inch mesh around the base of the traps.

CATTLE GRUBS

The experiments in cattle-grub control, begun two years ago in cooperation with the Virginia Agricultural Experiment Station in the valley known as Burkes Garden, Va., were continued. Although most of the stock owners in the valley reported marked benefits from the work of the previous year, a moderate infestation of grubs was still to be found in local animals. The facts that this work was done by the farmers on a purely voluntary basis and that a great many infested animals were brought into the valley during the season when the grubs were maturing and leaving the hosts are undoubtedly responsible for the failure to eliminate the pests more rapidly from the area under treatment. Further experimental work was done on the application of insecticides in powdered form to the backs of cattle infested with grubs. These experiments demonstrated the value under practical conditions of natural tobacco dusts of high nicotine content when applied to the backs of cattle. Much work along this line still remains to be done.

FLY CONTROL UNDER FARM CONDITIONS

The various procedures in connection with control of flies under conditions prevailing on farms were given further tests in cooperation with the Bureau of Dairy Industry on the Beltsville, Md., farm of the department. Home-

made pyrethrum-kerosene extract used as a spray was shown to be very effective in controlling the horn fly. Although the stable fly and the house fly were reduced in numbers, the inefficacy of fly sprays, except when used in conjunction with every known method of preventing fly breeding, was fully demonstrated.

SHEEP-SCAB MITE AND GOAT LOUSE

Studies of the biology, host relationships, and longevity under varying conditions of the common sheep scab mite and several species of goat lice were continued in cooperation with substation No. 14 of the Texas Agricultural Experiment Station and at the Dallas, Tex., laboratory.

CREEPING ERUPTION OF MAN

The investigational work relating to creeping eruption, which has been under way during the past few years, has been brought to a close. Further valuable information has been gained regarding the distribution of the parasite and the disease produced by it, and the ways of differentiating this particular type of eruption from that caused by the larvæ of certain insects. The results of these investigations are being made available to the medical profession and others interested by a series of papers published in medical journals.

MOSQUITOES

Investigations of the biology and habits of malaria mosquitoes were continued at Mound, La., under the direction of W. V. King. Special studies of the ecology of malaria mosquitoes were continued in the Delta region of northeastern Louisiana. These studies dealt in some detail with the food requirements of the larvæ and the relation of various plankton groups to local abundance. Further experiments have been carried out with sprays designed to kill and repel mosquitoes, and investigations of ways of making Paris green more effective in the destruction of the larvæ have been continued.

INVESTIGATIONS OF INSECTS AFFECTING FOREST AND SHADE TREES

This work has been continued under the direction of F. C. Craighead, as in former years.

PINE BARK BEETLES

Heavy increases during 1927 of the losses caused by the western pine beetle in the commercial stands of Oregon and California have emphasized the necessity for working out a better understanding of the natural factors that cause these periodic epidemics. Investigations on this problem were enlarged and concentrated during the season of 1927 on the Sierra and Modoc National Forests of California. Likewise the survey of 34 check plots on the southern Oregon-northern California pine-beetle control project, totaling nearly 20,000 acres, was carried out again during the past summer in order that the cycles of the western pine-beetle infestation in these virgin forests might be followed. Many valuable data were obtained as to the class of trees selected by the beetle for attack, the types and sites of greater susceptibility, and the meteorological conditions which influence the seasonal abundance of the beetles. On the Modoc National Forest large sample plots have been established to determine the site and the quality of timber most susceptible to these outbreaks. It has been found, in general, that stands in which there is a high percentage of individual trees which are slow growing are the most susceptible to these losses. The resistance of individual trees to attacks of the beetle has been studied by means of caging beetles and artificially inducing the attack. Through this method a better understanding of the character of resistant trees has been gained. It is proposed to apply this information in the selection of trees that are to be left on logging areas for seed production and cover. The results of these studies indicate that selective logging, by removing the susceptible and leaving the resistant trees, will materially reduce the losses caused by this beetle in the more mature stands of timber. Two small sample areas in Modoc County have been marked and logged experimentally with this object in view.

A study of the effect of predators and other enemies of the western pine beetle was continued. The past season's results show that several predators are important in the natural control of the western pine beetle and indicate that improvements in artificial control can be so timed that the greatest possible service from these beneficial insects will be secured.

Several years of investigation on windfalls that arise unexpectedly in the forest and induce bark-beetle outbreaks were completed in 1927. Records have been kept since 1921 from two areas of storm-felled trees in California which show that windfalls are often followed by severe but short-lived bark-beetle outbreaks in the surrounding standing timber. Often more timber is killed by the resulting bark-beetle epidemics than is destroyed by the original storm.

Investigations of the broader aspects of the biology of *Dendroctonus monticolae* in lodgepole pine were continued during the past season on the east fork of the Bitterroot River in Montana. The objects of these studies are similar in a way to those described above, namely, to obtain more definite information relative to the factors which may contribute toward the rise and fall of epidemics, and information leading to more economical methods of control. Various methods of artificial control were tested on an experimental basis, some of which show promise of being economically feasible. These consisted principally of felling, girdling, and otherwise treating the infested trees shortly after attack. Information was obtained on the habits and development of these insects, the extent of their flight, and the ratio of beetles attacking the trees to those emerging; and some of this has found ready application in the large control project now being conducted on this same infestation.

AIRPLANE SURVEYS

In connection with the Modoc epidemic and in cooperation with the Forest Service, an airplane survey of the infested areas was made in the fall of 1927. There has been considerable progress in the adaptation of aerial photographic methods to the needs of insect-reconnaissance work.

PROBLEMS UNDER INVESTIGATION IN SOME OF THE STATES

Cooperation with several of the forest experiment stations on insect problems having a direct bearing on forest management has continued on about the same basis as in previous years. Unfortunately it has not been possible to extend the bureau's services in this respect or to meet the demands for enlarging the work of this character.

Interest in the growing of larch in the Lake States has centered atten-

tion on the larch sawfly. The observed fluctuation in the abundance of this insect from year to year led to certain experiments to determine the causes influencing survival and mortality of the hibernating cocoons. It was found that the sawfly is best able to pass the winter in the sphagnum moss characteristic of the swamp forest, while on higher ground greater mortality occurs. Certain biotic factors, as parasites, fungi, and small mammals, were also of importance in lowering the percentage of survival. Of these mice and shrews were found to destroy from 50 to 80 per cent of the hibernating cocoons. It would appear from results of this preliminary work that superficial drainage of hemlock swamps offers a possible means of reducing the probability of outbreaks by the larch sawfly.

At Halsey, Nebr., the introduction of parasites was continued in an attempt to check the tip-moth infestation in Forest Service plantations. Collections were made from the vicinity of Flagstaff, Ariz., in the hope of obtaining species more effective on western yellow pine. Of those liberated previously, one (*Campoplex frustanae* Cushman) has already become established.

In the New England States the program of investigation outlined several years ago for studies relating to the white-pine weevil has been nearly completed. The results have confirmed observations of earlier workers showing that under forest conditions practically satisfactory weevil control can be obtained through appropriate silvicultural practices.

Following the exceptional drought of 1925 in certain portions of the piedmont region, several outbreaks of the hickory bark beetle developed. This insect is rarely destructive so far south. At the present time, following normal precipitation in 1927, these outbreaks have all subsided.

A limited amount of work has been conducted at Starke, Fla., in cooperation with the Southern Forest Experiment Station, on the turpentine borer. This beetle causes a high percentage of cull in lumber sawn from turpented trees and is likewise instrumental in so weakening the turpented trees that they are readily subject to wind-throw. It has been demonstrated that on experimental plots of the Forest Service all damage by this insect can be prevented by the adoption of conservative practices, such as the

standard Forest Service regulations, in turpentine operations. The results of several of these studies have been described in publications.

INSECT PROBLEMS IN THE NATIONAL PARKS

During the year practically all serious epidemics which have been mentioned in the annual report for 1927 have come under complete control; in general, therefore, the insect situation on the national parks is very good. The only serious situation which now exists is that on the Rocky Mountain National Park, where control against the Black Hills beetle is being conducted under the bureau's supervision. Funds are available to treat all the infested timber, and it is hoped that no further work will be needed next year.

STATUS OF THE MORE IMPORTANT BARK-BEETLE EPIDEMICS AND CONTROL PROJECTS

The Big Hole Basin control project of Montana, which was instituted in 1926, was continued during the season of 1927. The purpose of this project is to prevent through direct control measures the spread of an epidemic of the mountain pine beetle, which is threatening valuable lodgepole pine stands to the south. In combating this epidemic the Big Hole Basin was selected as a zone of defense, as it lies across the head of the infestation. A few miles to the north and across the Continental Divide to the west this epidemic exists in solid blocks of infested trees, which cover an area of many square miles. This year's work will probably demonstrate whether with limited funds capable of treating only the advance infestation it is practical to continue the attempt at checking the spread of this epidemic.

In cooperation with the Forest Service and private timber owners who contributed to the expenses of the work a survey was made of a heavily infested district on the Modoc National Forest in California. On this district during the past few years the losses have increased tremendously, until in 1927 a loss of 184,000,000 board feet, representing about 3.26 per cent of the pine stumpage in 430,000 acres, was sustained. The timber owners and community have become aroused over the seriousness of the situation and are working with the Bureau of Entomology and the Forest Service to devise some means of remedying the situation. The expense of direct control on a project of such magnitude would be enormous, and it is hoped, therefore,

that a plan involving utilization of the timber will be practical.

INSECTS AFFECTING FOREST PRODUCTS

Many additional preservative treatments for the protection of wood in contact with the ground have been tried in the experimental plots on Barro Colorado Island, Panama, during 1927. As a supplement to these tests of wood preservatives, model, or demonstration, termite-proof buildings have recently been constructed in Panama, these being built entirely of timber impregnated with standard chemical preservatives or constructed of termite-resistant woods grown in the United States. These tests are conducted by the Bureau of Entomology in cooperation with the Forest Products Laboratory of the Forest Service, the Chemical Warfare Service, the Bureau of Standards, and several public-service corporations. Additional tests of mortars of various composition were made in masonry foundation walls erected for the purpose. These are designed to determine the proportions and chemical constituents of the mortars most effective in preventing passage of termites through them.

During 1927 the Pacific Coast Building Officials' Conference adopted certain provisions which were recommended by the Bureau of Entomology for inclusion in mandatory building codes, to prevent damage by termites to buildings. The Territory of Hawaii is likewise considering similar provisions, which, however, will be slightly more inclusive than those recommended for continental United States. These provisions should add not more than 2 per cent to the initial cost of the building, and they should constitute a form of insurance either to the owner or to the person financing the structure.

During the early summer of 1928 the Forest Products Laboratory of the Forest Service initiated a mill study which will be conducted on logging operations in the southern Appalachians. The Bureau of Entomology is cooperating in this investigation in an effort to determine the amount and extent and the resulting loss in grade of the more common defects due to insects in the living timber of this region.

INSECTS AFFECTING SHADE TREES AND HARDY SHRUBS

Activities relating to insects which attack shade trees and hardy shrubs have consisted principally of the han-

dling of inquiries and correspondence. These communications continue to come to the bureau in great abundance, evidencing an important interest in this subject.

Experimental work on the control of the boxwood leaf miner by fumigation with hydrocyanic-acid gas has been actively continued in cooperation with the Pennsylvania State Department of Agriculture, and much attention has been given to examining, advising, and supervising control of infestations by the boxwood leaf miner about Washington, D. C., especially on public grounds. The details of the methods of fumigation and the other means for controlling this species which have been worked out in the course of these investigations are being prepared for publication.

BEE-CULTURE INVESTIGATIONS

The work of the bee culture laboratory has continued under the direction of James I. Hambleton, with headquarters at Somerset, Md.

BEHAVIOR OF BEES

A comparative study of the seasonal brood-rearing activity with the various races of bees has been continued, and one paper dealing with the brood-rearing activity of the Cyprian race has been published outside the department. Computations of the data collected on package bees during 1927 have been made, and a paper on this subject will shortly be ready for publication. Continued tests have shown that the artificial insemination of queen bees is practicable from the standpoint of genetics, and an endeavor is being made to refine the technic now in use. Along with this work, a biometric study of the various races has been undertaken to determine their distinguishing physical characteristics other than color, and also to afford a means of identifying various racial strains desirable for breeding purposes.

The work on the reactions of honeybees to light has been continued, and three main facts have been ascertained as follows: (1) The relative stimulating efficiency of the various regions of the visible spectrum has been worked out, and may be plotted as a curve which corresponds somewhat to the curve for the human eye in that the yellow-green is the most efficient, but differs from the latter in that red is less efficient and violet more efficient; (2) data so far secured indicate that bees can distinguish intensities of

white light that differ as much as 1:4, but can not distinguish differences as small as 1:1.3; and (3) that bees are able to differentiate certain colors from one another on the basis of the quality (chroma) of the color and not its quantity (brilliance) alone and that the number of chromas differentiable by bees is probably at least six, namely, ultra-violet, violet, blue, blue-green, green, and red.

In experiments dealing with the flight activity of bees two new instruments have been developed which make it possible to record quantitatively the amount of flight indulged in by bees when they are free to fly under natural conditions. One of the instruments is so designed that it makes a continuous pen record of flight activity. It is hoped through the use of these instruments to obtain data relative to the effect of various weather factors upon flight activity without the interference of the stimulus to fly caused by the presence of nectar in the field. Coefficients of correlation dealing with the effect of weather factors upon flight activity have been computed.

PHYSIOLOGY OF BEES

The study of the mortality of adult bees during the winter months has been continued, daily records being kept of the deaths occurring in a number of colonies. The effects of weather factors, age of bees, and stores have been given particular attention. Because of the enormous winter losses sustained annually throughout the United States, a loss roughly estimated close to \$8,000,000, this problem is deemed a most important one.

Cage tests on the longevity of adult bees during the active season were carried out. This included the effect upon longevity of feeding with various sugar sirups and queen-cage candies, and of differing environmental conditions.

Serious losses have been experienced in connection with importations of adult bees from Europe, involving both the queens and accompanying worker bees. Work is under way to develop methods which will reduce such losses, the results of which should be of value to our own package-bee and queen-rearing industry.

Experiments are in progress to determine just how the application of heat affects the color of honey and to determine to what extent honey may be heated to retard granulation in

commercial practice and still not destroy the diastatic enzymes. The effects of age and sunlight upon color changes of honey are also being given attention.

DISEASES OF BEES

Eight hundred and fifteen samples of brood and adult bees have been examined for diseases during the year. Regular routine analyses for the following bee diseases are now being made: American foul brood, European foul brood, sac brood, Nosema disease, septicemia, mycosis, Amoeba disease, and Isle of Wight disease. A new disease of adult bees caused by a heretofore unrecognized organism, *Bacillus apisepcticus*, was found in the apiary of the bee culture laboratory. A preliminary report on this disease was published outside the department. Altogether 24 samples of bees showing this disease have been sent to the laboratory. These cases were well scattered over the United States, indicating that the disease is quite prevalent, although nothing can be said at this time as to how serious it may be. A disease of recently emerged adult bees, which reached the nature of an epidemic among day-old bees, was also discovered during the year, the causative organism having been determined as *Mucor hiemalis*. The practicability of using formaldehyde gas to disinfect American foul-brood combs is being determined in a large series of tests. If this method of treating combs is found efficacious it should prove to be considerably less expensive than methods now employed to disinfect infected material.

The parasite of adult bees *Acarapis woodi*, prevalent in Europe, has not been detected in any of the importations from foreign countries received during the year, and no indications have been found that this parasite occurs in the United States.

BEEKEEPING REGIONS IN THE UNITED STATES

A series of important studies dealing with the cost of honey production and methods of apiary management was started this spring in the intermountain States in cooperation with the Bureau of Agricultural Economics and the beekeeping specialists in the States where the studies are being conducted. Under the supervision of two representatives of this department—one from this bureau and one from the Bureau of Agricultural Economics—daily labor records are being

kept in about 50 large commercial apiaries. Close attention is also being given to methods of apiary management and honey-house equipment. Honey marketing has made little advance in recent years, and in order that beekeepers may hold their own in the competitive marketing field it is necessary to have a reliable basis of estimating the cost of production under modern methods and with modern equipment.

Because of the widespread belief that honey is not altogether a natural food but has been subjected to a manufacturing process before it is placed on the market, and because of the scant knowledge possessed by the average consumer concerning different flavors, colors, and types of honey, a four-color educational poster has been prepared as a guide to honey consumers.

INTERMOUNTAIN BEEKEEPING METHODS

An experimental apiary consisting of 50 colonies of bees and 30 nuclei has been established at Laramie, Wyo. In this apiary experiments dealing with the spread of infectious bee diseases have been continued, the work being confined largely to determining the minimum number of spores of *Bacillus larvæ* that would establish disease. It was found that as low as 750 spores per cubic centimeter when fed in a suspension of sugar sirup would cause disease in experimental colonies. A method is being devised to determine the spore content of honey so that the necessity for treating supers and other accessory parts of the hive and honey-house equipment may be determined, and also to ascertain what part commercial shipments of honey play in the dissemination of bee diseases.

Apiaries at Fort Collins, Colo., Laramie and Lander, Wyo., and Fromberg, Mont., have been selected for studying methods of wintering, three different methods being used at each place. This year's results at the Laramie apiary seem to point to granulated honey as being one of the prime causes of spring dwindling.

A section of the Penrose bad lands east of Powell, Wyo., was selected for continuing-flight experiments which were started last year. Early results indicate that bees will fly at least 7 miles in one direction to obtain nectar if forced to do so. It is not economical, however, for a beekeeper to locate his apiaries so far from the source of nectar.

INSECT-PEST SURVEY

The work of the insect-pest survey has been carried on, as in the past, under the direction of J. A. Hyslop.

The survey has now functioned for seven years and is recognized as one of the important cooperative activities of the bureau with the agencies concerned in applied entomology in the several States.

By an informal arrangement with a survey in Canada, instituted a few years after the United States insect-pest survey was inaugurated, the bureau survey receives notes on current insect conditions in the Dominion. Last year the Hawaiian Sugar Planters' Association and the Ernest Pauahi Bishop Museum started an insect-pest survey of the Pacific, and, through the courtesy of the Hawaiian Entomological Society, exchanges of outstanding entomological features with that survey are made.

A new project was inaugurated during the year, that of cross-indexing the entire survey records under the host-plant names. So far there have been thus indexed only two-fifths of the American records, but the work already covers more than 400 genera of plants, including over 500 species, with their insect enemies.

During the year the survey completed volume 7 of its monthly bulletin, consisting of 10 numbers, 399 pages of text, and 44 pages of index, and also completed the first 4 numbers of volume 8, comprising 134 pages of text material.

TAXONOMIC INVESTIGATIONS

The work on the identification and classification of insects has continued under the general supervision of S. A. Rohwer. Inasmuch as Mr. Rohwer has had to devote so much time to general administrative work, more detailed supervision has been under the direction of Harold Morrison since August, 1927.

As has long been the practice, the taxonomic work has been conducted in cooperation with the United States National Museum, the specialists of the bureau being given desk room and access to the extensive collections of the Museum. Because of the large number of insects which are received for identification from workers of the department and its cooperating agencies, this cooperation is essential and economical. It gives the specialists access to extensive reference collections

and does away with the necessity, which otherwise would occur, for the bureau to maintain its own reference collection.

The work done by the specialists employed under this unit is primarily in the nature of a service, and consists in furnishing authentic identifications to field workers, thus making it possible for them to have access to the work done by previous investigators. In order that the identifications furnished by this unit may be properly made and based on the most up-to-date information, it is very important that investigations be conducted on the taxonomy of the groups which are most important to American agriculture. The service requested of the specialists in this unit has been so pressing and of such volume that there has not been sufficient opportunity for them to conduct the necessary research. An effort should be made to increase the personnel so that the specialists will have the time to conduct the research necessary to enable them to furnish the up-to-date information required. This expansion is highly desirable, because if the species belonging to any unit are properly classified and the information concerning them coordinated, identifications can be made much more promptly.

During the year 12,074 identifications have been made for various offices of the bureau and department and for collaborators. A very large percentage of these identifications has consisted of specimens referred to the bureau by the inspectors connected with the Federal Horticultural Board.

In the following tabulation the numbers of identifications made during the last two fiscal years are compared:

Orders	Identifications, 1926-27	Identifications, 1927-28
Hymenoptera.....	2,736	1,742
Coleoptera.....	3,329	2,880
Lepidoptera.....	1,694	2,662
Diptera.....	2,333	1,706
Orthoptera and Neuroptera..	620	577
Ectoparasites and small orders	908	864
Hemiptera.....	443	607
Isoptera.....	16	-----
Coccidae.....	(1)	2,200
Total.....	12,079	13,238

¹ Coccidae not reported in 1927.

In addition to the furnishing of identifications, the specialists in this unit have rendered assistance to research workers throughout the United

States and to their colleagues in foreign countries, and have supplied information concerning the distribution and host relationships of economic insects.

During the year the work has been rearranged, and seven projects have been established. These projects bring together the identification work done on some of the more important economic groups of insects. The projects established are the following:

1. Coleoptera—beetles, weevils, etc.
2. Lepidoptera—moths and butterflies.
3. Diptera—two-winged flies.
4. Hymenoptera—chalcid flies, ichneumon flies, wasps, bees, ants, etc.
5. Orthoptera—crickets, grasshoppers, locusts, etc.
6. Ectoparasites and mites—lice, fleas, etc.
7. Coccidae—scale insects.

In addition to the identification-service work, which is common to all of the projects, certain investigations have been conducted on these projects, of which only a few of the more important ones are given in the following summary:

COLEOPTERA

A revision of the flat-headed borers belonging to the genus *Agrilus* has been completed. Studies have been conducted on the larvæ of the Chrysomelidæ, the group to which the Colorado potato beetle and the cucumber beetles belong. A revision of the genus *Trichobaris*, a group of weevils containing such economic forms as those which bore in stalks of tobacco and related plants, has been completed. Considerable progress has been made in coordinating the taxonomic information relating to predacious forms belonging to the families Cleridæ and Coccinellidæ.

LEPIDOPTERA

Considerable progress has been made toward the completion of a monographic paper on the moth family Tortricidæ, which includes many forms of considerable economic importance, such as the codling moth and oriental fruit moth. Much progress has been made in arranging the collections and bringing together necessary information on the larvæ of all lepidopterous insects (butterflies and moths).

DIPTERA

A paper is in preparation setting forth the characters by which the vari-

ous forms of fruit flies likely to be introduced into the United States may be recognized in both larval and adult stages.

HYMENOPTERA

The work done under this project this year has been somewhat hampered by the fact that Mr. Rohwer has been unable to do the work previously conducted by him, and because two of the leaders have been away from headquarters for extended periods. One of these investigators, A. B. Gahan, spent a considerable time in Europe examining collections in foreign museums.

ECTOPARASITES AND MITES

Considerable progress has been made on a catalogue of the North American mites. Investigations on scorpions and fleas have progressed satisfactorily, and an extensive paper dealing with those mites which are injurious to animals is in the hands of the publication office.

COCCIDAE

Some progress has been made in studying the extensive collection of scale insects formed by one of the foremost investigators, Maskell, which had been forwarded for restudy by specialists.

C. F. BAKER COLLECTION

During the year, through the bequest of C. F. Baker, who died in the Philippines, the National Museum came into possession of the extensive collection of insects which he had formed during his long stay in the Orient. This collection contained representatives of many species which were not available to the bureau specialists, and many of these are of considerable economic importance, some of them being hosts of the parasites of such pests as the Japanese beetle and the European corn borer. One of the bureau specialists, R. A. Cushman, working in close cooperation with the museum, went to the Philippines to arrange for the packing and shipment of this very valuable collection. The collection has been safely transferred to Washington and is now available to all of the bureau specialists. It should assist materially in the identification of the specimens which are submitted by investigators in the Orient or intercepted on products coming from there.

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